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ABSTRACT

This study is comprised of five major sections, each of which focuses on a central linguistic issue germane to the understanding of the general phonetic characteristics of languages. The sections include: (1) a comparative study of terminal consonant releases; (2) the influence of consonants upon contiguous vowels --phase 1: vowel duration; (3) vowel-color of German /E/ sounds; (4) comparative phonetic study of /1/ in American-English, French, German, and Spanish; and (5) the teaching of "clear" versus "dark" /1/ in English, French, German, and Spanish. Detailed description of experimental procedures is accompanied by extensive statistical documentation and analysis largely accompanied by charts, tables, and graphs. The comparative phonetic study of /1/ contains numerous samplings of wide band spectrograms illustrating contrastive articulatory features of German, Spanish, French, and American-English. (RL)

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FINAL REPORT

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THE GENERAL PHONETIC CHARACTERISTICS OF LANGUAGES

André Malécot

University of California
Santa Barbara

July 1971

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
OFFICE OF EDUCATION

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A COMPARATIVE STUDY
OF
TERMINAL CONSONANT RELEASES

PART ONE

DATA COLLECTION

The study began with the compilation of lists of words in French and English containing every possible terminal -VC and -CC combination. We reached a total of 255 items in French and 400 in English--the discrepancy is largely explained by the greater number of vowels in English. All of the consonants occurred after a stressed vowel, with the single exception of English schwa + consonant. In an attempt to maintain the same prosodic context throughout, the final syllable was made to occur as the last of four: Monosyllabic items were preceded by the carrier phrase "One, two, three,...," disyllabic items by "One, two,...." Then, the items were recorded on magnetic tape under optimum laboratory conditions. Three speakers were used for each language: three Californians, ranging in age from 20 to 35 years and speaking a more or less standard variety of General American, and three Frenchmen, of roughly the same age group and speaking an upper middle-class variety of Parisian French.

The next step was to make sound spectrograms of the recorded utterances. In an attempt to find the technique that would yield the maximum phonetic information, we proceeded in the following manner: For the first French speaker, we made two spectrograms of each utterance, once with the amplifiers set at a normal reproducing level, and once at a high distorted level, the latter hopefully to bring out all the details of the releases, which are relatively weak. For the second French speaker, we again made two spectrograms of each utterance, but this time with two different instruments, the first an older slow reproducing, tube-amplifier model (5 min.), the second a recent fast reproducing, solid-state model (1.3 min.). The spectrograms made with the slow reproducing instrument, with all controls set at normal values, proved to be the best. Greater precision in marking onset and cutoff points is possible with this machine. Accordingly, the results to be presented in this report are based on narrow-band (45 Hz) spectrograms with amplitude display, made with a standard Kay "Sona-Graph". Even at best, however, it is impossible to be sure about the minute spectral detail of entities as weak as are many of the releases. For that reason, our analysis of the phenomenon in question is limited to its duration and general character.

ANALYSIS OF DATA

It soon became apparent that the duration of releases, expressed in absolute values, contributes little or nothing to our understanding of their nature. Their real interest lies in the relationship between their duration and that of the steady-state portion of the consonant and that of the preceding vowel. These relationships are shown in the accompanying charts. As to the general character of the releases, they appear to fall into six categories as follows: Type 1 is a set of embryonic three formant vowel transitions with F1 somewhat louder than F2 and F3. Type 2 is roughly the same except that the release is whispered and the formants are consequently filled with white noise rather than periodic energy. Type 3 is essentially an aspiration, resembling Type 2, but for F1, which is missing. Type 4 is an affrication, appearing on the spectrograms as a wide band of noise, resembling the turbulence of the fricative consonants. Type 5 is a burst, which shows up as a vertical spike, extending over a varying range of the spectrum and followed by silence. Type 6 is restricted to the fricatives and shows up as an increase in noise intensity at the end of the steady-state interval. Although these characterizations appear to be valid on the basis of our data as a whole, individual samples are not always easily ascribed to a given type.

RESULTS FOR FRENCH

1. General observations. Terminal stops always end with a release. This release is generally longer after a given sonant (/b, d, or g/) than after its voiceless cognate. It is longest after the post-vocalic dentals (/t,d/) and the post-consonantal labials (/p,b/). Terminal fricatives have only sporadic releases: For consonants of this mode, the surds (/f,s,ʃ/) occurring after vowels are practically never released; after consonants they generally have releases of minimal duration. Releases occur more often after the sonants (quite often after /v/, after /z/ only after vowels, and after /ʒ/ only after consonants). Terminal nasal consonants and /l/ are almost always released. These releases are of fairly constant duration, whether the consonants follow vowels or other consonants. On the other hand, post-vocalic /r/ is practically never released in a manner that is evident on spectrograms.

2. Comparison of durations according to consonantal features. The release is longer after voiced consonants (in both -VC and -CC contexts) than after unvoiced consonants and, as we have seen, occurs more frequently after stops than after fricatives. With respect to manner of articulation, the releases increase in duration, as we go from stops to nasals to fricatives--the duration of the steady-state portion, however, presents quite a different picture. The effect of phonetic context is that, with the exception of the fricatives, the release is generally a bit longer when the consonant follows a vowel than when it follows another consonant. Place of articulation has the following effect: Labials have the longest releases, followed by the palatovelars, then the dentals and finally the pharyngeal /r/. The total duration of the consonants follows the same order. When steady-state duration is considered separately, the palatals are the longest, followed by the labials, then the velars and finally the pharyngeal /r/.

3. The influence of terminal consonant effects on the duration of final syllable segments: (a) When the final syllable ends in a stop, the following relationships prevail: Syllables ending in voiceless stops are slightly longer than those ending in voiced stops. Syllables ending in dentals are longer than those ending in labials, and those ending in palatals are the shortest. Voiceless stops (their steady-state plus release) are longer than their voiced cognates. The vowel is always longer before sonants than before surds--this further corroborates the data presented in Chapter III of this report. Vowel duration, furthermore, correlates with the place of articulation of the following consonant: it is longest before dentals, shorter before velars and shortest before labials. (b) When the final syllable ends in a fricative, the following observations emerge: Syllables ending in /s/ are relatively long, while those ending in /z/ are short. Inversely, syllables ending in /v/ are longer than those ending in /f/. With respect to the individual phonemes, the voiceless fricatives are longer than their voiced cognates, while the vowel is longer before the sonants than before the surds. (c) When the final syllable ends in a nasal or a liquid, the following relationships appear: The duration of the syllable as a whole is comparable to that of syllables ending in voiced stops--see above. Palatal /ɲ/ is the longest consonant, while the vowel preceding it is the shortest. Pharyngeal /r/ also has a short duration, and the preceding vowel is extremely long. The durations of

terminal syllables ending in /j/ are similar to those of syllables ending in /g/.

4. Comparison of vowel, consonant and syllable durations as a function of voicing/voicelessness. Not only are vowels longer before sonants than before surds, they are also longer before voiced fricatives than before voiced stops. The duration of the consonant varies inversely with the duration of the vowel. The magnitude of the difference between the two durations in question is greater among the fricatives than among the stops, and it is maximal in the sequence /-Vr/.

5. Comparison of vowel, consonant and syllable durations as a function of mode of articulation. The durations of the two segments of the stops together are almost identical, respectively, (within 3 msec) to those of the nasals. This would appear to confirm a currently popular view that nasal consonants should be classified as stops.

6. Comparison of terminal syllable segments as a function of place of articulation. The pharyngeal /r/ distinguishes itself from all the other consonants in that in terminal -VC syllables, its duration is extremely brief, while that of the preceding vowel is extremely long. Usually the relationship is the opposite, the consonant being longer than the vowel. The total duration of -VC syllables remains about the same for all points of articulation. These durations are thus distinctive only in setting pharyngeal /r/ apart from all the other consonants in terminal position.

7. Distribution of various types of releases. The types have already been enumerated and described--see section no. 1 above. The stops are never unreleased; type-1 (embryonic vowel) dominates except in the case of /t/; type -2 (whispered vowel), type -3 (aspiration) and type -4 (affrication) occur almost exclusively after /t/ and /k/; type -5 (burst) is very rare--we had a single occurrence of it, after /k/--; and type -6 (intensity increase) does not occur. The fricatives show much less variety than the stops with respect to release types. Most often they are unreleased; type -1 (embryonic vowel) occurs only after sonants; type -2 (whispered vowel) is extremely rare; type -3 (aspiration), type -4 (affrication) and type -5 (burst) do not occur; and type -6 (intensity increase) occurs only after labials. After liquids, semi-consonants and nasals, the following observations emerge: /j/ and /l/ are most often unreleased. The pharyngeal /r/ presents

special problems. No clear acoustic phenomenon shows up after the 'hold' portion of that consonant, but its formants show some transitions, reflecting a separation of the articulators. Any decision as to the precise point at which the release begins is necessarily arbitrary. This, together with the progressive de-voicing of this consonant makes further examination of its release speculative. After nasal consonants, the release is almost always type 1 (embryonic vowel).

RESULTS FOR ENGLISH

1. General observations. In the conditions of the present study, the terminal stops are always released. These releases are longer when a stop follows a vowel than when it follows a consonant. Unlike French, the duration of the release does not appear to vary as a function of the voicing/voicelessness of the stop: while the release of /b/ is longer than that of /p/, the converse obtains for the alveolars and velars. Fricatives show only intensity increase: the voiced/voiceless distinction for this class of consonants is obviously made mostly, if not entirely, on the basis of durations--see below. Nasals and liquids are quite consistently released, although the release of /l/ is sporadic. The releases of nasal consonants are generally longer than those of liquids. The duration of the steady-state portion of the nasal consonants is close to that of voiced stops, while that of the liquids is much shorter.

2. Comparison of durations according to consonantal features. The release is slightly shorter for surds than for sonants, but the total duration of the consonant (steady-state plus release) is longer for the surds than for the sonants. Fricatives are of course excluded from this, as type 6 (intensity increase) is not measurable in terms of duration. However, the steady-state portions of the voiced fricatives are longer than those of the stops, and the same relationship holds for the voiceless fricatives and stops. With respect to manner of articulation, the releases of the stops are the longest, followed by those of the nasals, with the liquids coming last. The total durations of the consonants rank them in a quite different order: The fricatives are the longest, followed by the nasals, then the stops, and finally the liquids. The magnitudes of differences in overall consonant duration are smaller than those of the releases alone.

With respect to what precedes the final consonant, the releases, the steady-state, and the total duration of the consonant are longer after -VC than after -CC. The effect of place of articulation is as follows: Labial consonants have the longest releases. Those of alveolars, velars and the /r/ have releases of practically the same durations. The durations of the steady-state and of both consonantal segments combined are greatest for velars and smallest for /r/.

3. The influence of terminal consonant effects on the duration of final syllable segments. (a) When a final syllable ends in a stop, the following relationships prevail: In contrast to French, total syllable length is greater for final sonants than for final surds. Place of articulation affects the duration of syllables ending in voiceless stops but not those ending in voiced stops. Vowel duration is, of course, strongly determined by the voicing/voicelessness of the final consonant. The difference between the duration of the vowel and that of the stop is greater when the stop is voiced than when the stop is voiceless. (b) When the final consonant is a fricative, the following observations emerge: As in the case of the stops, syllables ending in a given fricative are longer when that consonant is a sonant than when it is a surd. The duration of the consonant itself doubles as a surd is substituted for its sonant cognate. (c) When the final consonant is a nasal or a liquid, the following relationships appear. In both cases, vowel length correlates with syllable length. With the exception of velar /ŋ/, the vowel is generally longer than the final consonant. Liquids are shorter than nasals.

4. Comparison of vowel, consonant and syllable durations as a function of voicing/voicelessness. Voiced consonants of all classes lengthen the preceding vowel, while their voiceless cognates shorten it. Voiced versus voiceless consonant durations in cognate pairs appear to be greater among the fricatives than among the stops.

5. Comparison of vowel, consonant and syllable durations as a function of mode of articulation. As in French, we find a similarity between stop and nasal consonant durations. Vowel plus fricative syllables have vowel durations comparable to those of vowel plus stop syllables, but their consonant durations are different.

6. Comparison of terminal syllable segments as a function of place of articulation. In this respect, the palatovelars differ from the other consonants in that (a) they have the shortest preceding vowels, (b) their vowel and consonant durations are practically equal, and (c) the entire syllable is maximal in duration. Contrastingly /r/ has the longest preceding vowel and the shortest consonant, and the entire syllable is minimal in duration. Thus, for all of the preceding cases, syllable length is determined primarily by consonant length. The converse is true for labial and alveolar consonants, in which syllable length is determined primarily by vowel length. In the case of these consonants, vowel duration is between that of vowel + velar consonant and vowel + /r/.

7. Distribution of various types of releases. An important difference between surds and sonants is noted in this respect: Surds do not have embryonic vowels as releases, while this type of release dominates among the sonants. There is a greater variety of release types among alveolar consonants than among labials and velars. In fact, the alveolars show every type of release. Type 3 (aspiration) and type 4 (affrication) occur only after /t/ and /k/ and very rarely after /p/ and /d/. Fricatives show either total absence of release or type 6 (intensity increase). Nasals and liquids (except for /l/) occur about an equal number of times with and without release. The lateral /l/ is never released. The nasals and /r/ frequently have type 2 (whispered vowel). The nasals occasionally show type 5 (burst) but never type 3 (aspiration) nor type 4 (affrication).

PART TWO

DATA COLLECTION

The second part of this study on terminal consonant releases began with the compilation of lists of words in German and Spanish containing every possible terminal consonant following the central vowel /a/. There were a total of 10 final consonants possible in Spanish, including the Castilian/θ/ and the affricate /ks/. In German there were 19 consonants, including the phonemic affricates /pf/ and /ts/. Logatomes were created with these same final consonants; in Spanish, they were of the type /maC/, in German, /naC/. The German logatomes were arranged as if they were nouns, i.e. ein Nat, etc. The German words and logatomes contained both long and short /a/. The words in isolation and in sentences and the logatomes were recorded on magnetic tape under optimum laboratory conditions. For Spanish, three speakers from Spain, two from Argentina and one from Mexico City were recorded. The five German speakers were from different parts of Germany, but all spoke a rather dialect-free standard High German.

Sound spectrograms of the recorded utterances were next made with a standard Kay "Sona-Graph". Several spectrographs and various techniques were used to enhance the display of the releases. Nearly all of the spectrograms were redone on two or more machines. Vowel and consonant durations were measured, and the types of releases were then classified. The release types were arranged somewhat differently than in the first part of this study on French and English. Type 0 is unreleased; type 1 is an embryonic vowel with three visible vowel formants; type 2 is aspiration, no F1 but F2 and above; type 3 is a burst, a sharp spike fill; type 4 is a burst followed by aspiration; type 5 is a burst plus friction, i.e. affrication; type 6 is a burst plus an embryonic vowel; type 7 is friction, a wide band of noise; and type 8 is an increase in noise intensity at the end of the fricative steady-state.

RESULTS FOR GERMAN

1. General observations. Since in standard High German final /b,d,g,v/ are prescribedly devoiced, there seemed no reason for listing such pairs as Rad/Rat as having different final consonants. Nevertheless, words and logatomes with spelled final b,d,g,v were used. One of the most interesting results of this study is the possibility that spelled final b,d,g,v are both perceived and produced differently than final p,t,k,f. The stops were always released; the releases of p,t,k tended to be longer than those for b,d,g. The fricatives were very seldomly released, but the affricates had the longest terminal release durations. The nasals and /l/ often had releases; /r/ showed only sporadic releasing.

2. Comparison of durations according to consonantal features. There is not a sharply delineated relationship between release durations; however, the following tendencies exist: /r/ has the shortest release duration, /pf/ and /ts/, the longest; spelled b,d,g have shorter releases than p,t,k; and stops tend to have longer releases than nasals or liquids. Total consonant duration relationships are similar to those of the releases: /r/ is the shortest; /pf/ and /ts/ are the longest; and /s/

and /ʃ/ are the next longest. Interestingly, consonant durations for *b*,*d*,*g* were the three shortest after /r/. Consonant durations for the remaining consonants were randomly distributed. There is a tendency for longer duration for labials than for velars or dentals, but this is not consistent throughout.

3. *The influence of terminal consonant effects on the duration of final syllable segments*. Since not all final consonants occur with both long and short vowels, syllable segment durations will be considered in two groups. First, those with long vowels show greater durations for the fricatives and affricates than for the stops, nasals and liquids. The syllables containing short vowels show this same relationship. The values for the syllables with short vowel plus stop are very close (within 3 centiseconds), and *b*,*d*,*g* show shorter durations than *p*,*t*,*k*. These relationships, however, are not found in the syllables with long vowel plus stop.

4. *Comparison of vowel, consonant and syllable durations as a function of voicing/voicelessness*. As was earlier stated, final spelled *b*,*d*,*g*,*v* are devoiced in standard High German. The present study, however, showed that there is a tendency to differentiate between these final consonants and *p*,*t*,*k*,*f*. Vowel durations were greater for *b*,*d*,*g*,*v* than for *p*,*t*,*k*,*f*, and consonant durations were less. Syllable durations seemed not to vary between the two groups; they were very similar for all the stops for example.

5. *Comparison of vowel, consonant and syllable durations as a function of mode of articulation*. /r/ consistently had the longest vowel duration and the shortest consonant duration. The stops had shorter vowel and consonant durations than did the fricatives. The nasals were randomly distributed among the other classes of consonants in both vowel and consonant durations, and the affricates showed the greatest consonant durations and average vowel durations. Stops, nasals and liquids had shorter syllable durations than fricatives or affricates.

6. *Comparison of terminal syllable segments as a function of place of articulation*. In contrast to the results in English and French, there is no clear ordering of duration relationships by place of articulation. Syllable length is not determined primarily by either consonant or vowel duration for specific classes of consonants. Labials often have greater vowel, consonant and syllable durations than dentals or velars, but this is occasionally reversed.

7. Distribution of various types of releases. In German only the stops, nasals and /l/ consistently show releases. An increase in intensity at the end of fricatives, noted earlier as a release type in English and French, occurs only infrequently. /r/ is seldom released. The affricates are also released, but only with type 5 release, burst plus friction. The stops most often show release type 4, burst plus aspiration; /k/ is released over 93% of the time with this type. Spelled b,d,g often have type 6 releases, burst plus embryonic vowel; this kind of release was never seen with p,t,k. The labials, p and b were the only stops to have type 7, a band of friction. Of the nasals, /m/ was least often released, /n/ was released 87% of the time, /ŋ/, 93%. When released, the nasals showed either type 1, embryonic vowel, or type 6, burst plus embryonic vowel 77% of the time. Types 2 and 4, aspiration and burst plus aspiration were the only other release types for the nasals. /l/ was released 93% of the time, usually with either an embryonic vowel or aspiration. Labials tend to show a greater variety of release types than do dentals or velars.

RESULTS FOR SPANISH

1. General observations. A study of terminal consonants in Spanish is obviously limited, first by the fact that there are so few consonants in final position--many authors only give /d,n,s,x,r,l/--; for this study, Castilian /θ/ and /t,k,ks/ were also added. Secondly, many speakers of Spanish do not release consonants in final position; they in fact often do not pronounce the terminal consonant at all. There is also no grouping of cognate pairs of voiced/voiceless final consonants. Therefore, the results in Spanish will not be as encompassing as they were for English, French or German.

2. Comparison of durations according to consonantal features. Even though there are relatively few terminal consonants in Spanish, release duration relationships similar to those in the other languages seem to exist. Other than the fricatives, which show little or no releasing, /r/ has the shortest release duration, /ks/, the longest. The stops are the next longest, the voiced stop being shorter than the two voiceless. The release durations for the liquid and nasal are clearly shorter than those for the stops. Total consonant duration relationships are very similar to those in German: /r/ shows the shortest duration; /ks/, the longest. Next longest is /s/, then the voiceless stops. Interestingly,

the voiced stop /d/, often pronounced as the voiced fricative /ð/, has the shortest consonant duration after /r/.

3. The influence of terminal consonant effects on the duration of final syllable segments. The relationships for total syllable duration, vowel plus consonant, are very similar to those for consonant duration alone. The /r/ consonant is the shortest, /s/ and /ks/ are the longest, followed by the voiceless stops. The voiced stop is short, and the other consonants are closely grouped together in the middle.

4. Comparison of vowel, consonant and syllable durations as a function of voicing/voicelessness. The relationships noted in the other languages do exist for the one cognate pair /t,d/ in Spanish. Vowel duration is greater, and consonant and syllable durations are shorter for /d/ than for /t/. Final /t/ occurs only seldom in Spanish, however, so phonemic differentiation based on voicing/voicelessness is rare in terminal position.

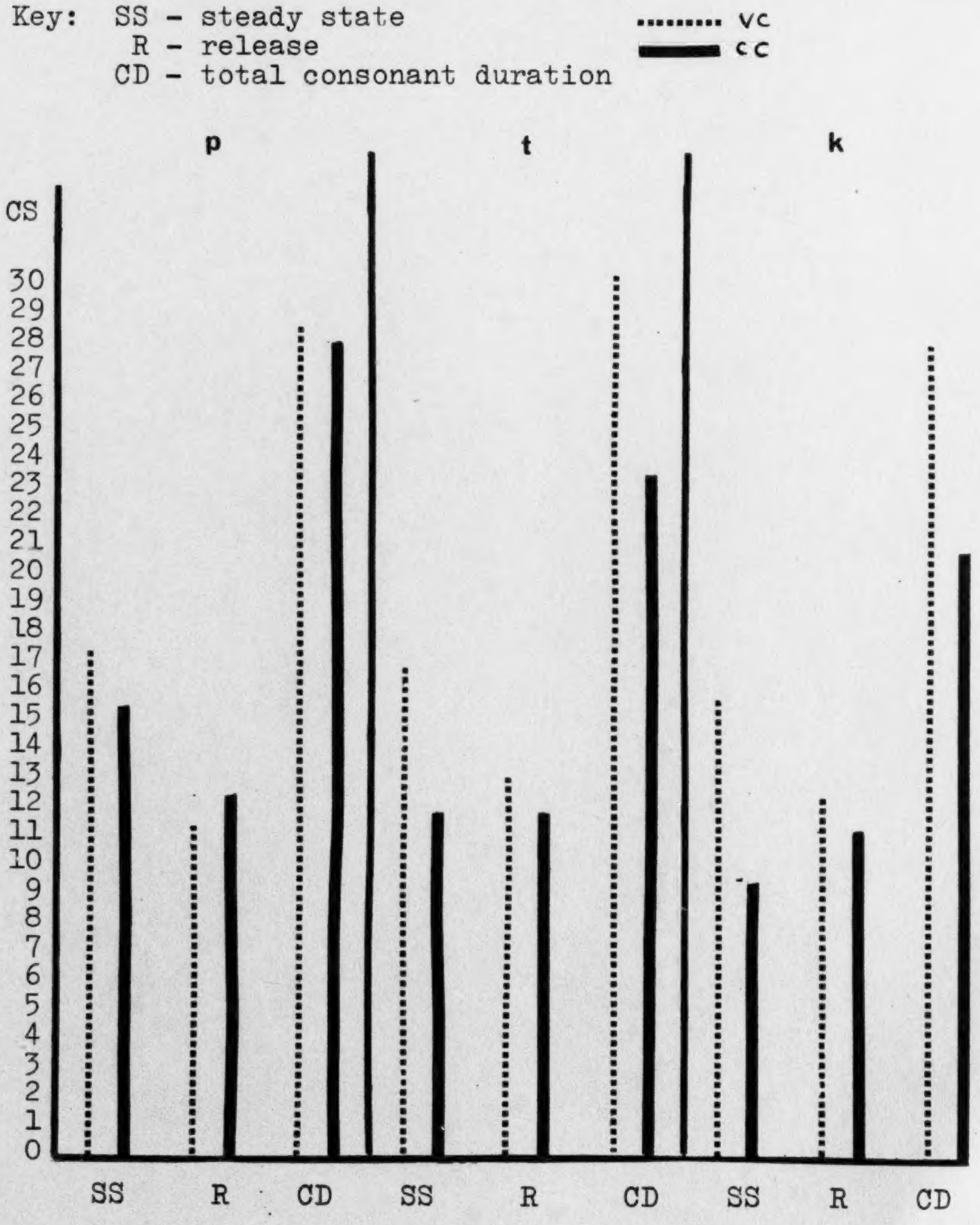
5. Comparison of vowel, consonant and syllable durations as a function of mode of articulation. The consonant /r/ had the next longest vowel duration and the shortest consonant and syllable durations. The affricate /ks/ had the shortest vowel duration, the longest consonant and the second longest syllable durations. The voiceless stops showed relatively long consonant and syllable durations and average vowel durations; the voiced stop had the longest vowel duration and very short consonant and syllable durations. /l/ and /n/ had average durations throughout.

6. Comparison of terminal syllable segments as a function of place of articulation. There is no rank ordering of syllable durations by place of articulation as was noted for English and French. Syllable duration appears primarily determined by consonant duration. Since there is no grouping of labials, dentals and velars in Spanish, syllable segment durations cannot vary as a function of place of articulation.

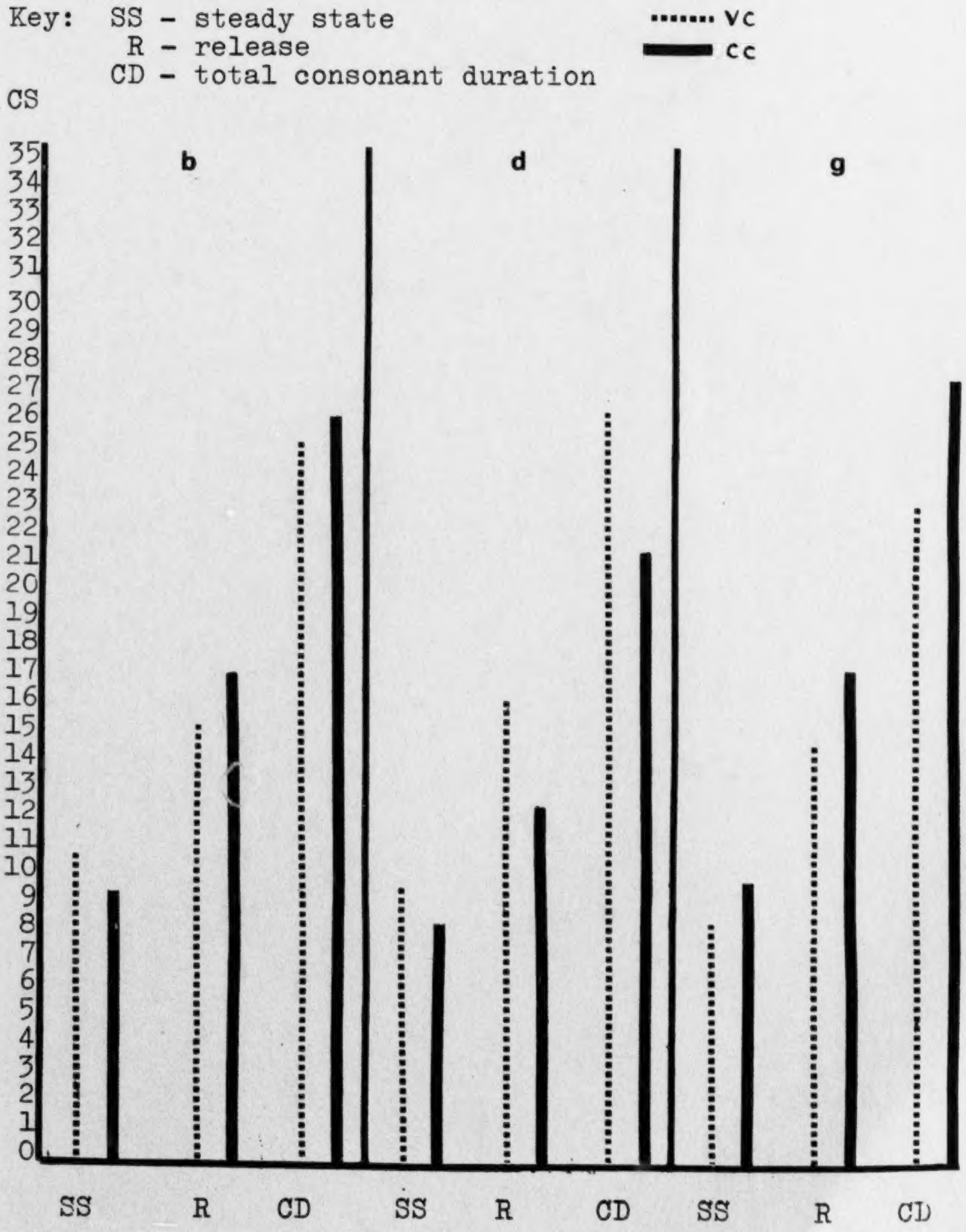
7. Distribution of various types of releases. In our present study /s/ was never released, /x/ was only released by one speaker, and Castilian /θ/ only once showed a release. /ks/ was released 80% of the time, always with either a type 5 or a type 7 release, burst plus friction or friction alone. /n/ and /r/ were only seldom released. The lateral, /l/, showed a release

35% of the time, when release occurred; it was most often type 1, embryonic vowel. The voiced stop /d/ was released just under one half of the time and showed a variety of release types, mainly embryonic vowel or burst plus embryonic vowel. The consonants /k/ and /t/ were released more than any other consonants in Spanish, 88% and 82% respectively. Release types 3 and 4, burst and burst-plus-aspiration, were by far the most common release types with the voiceless stops.

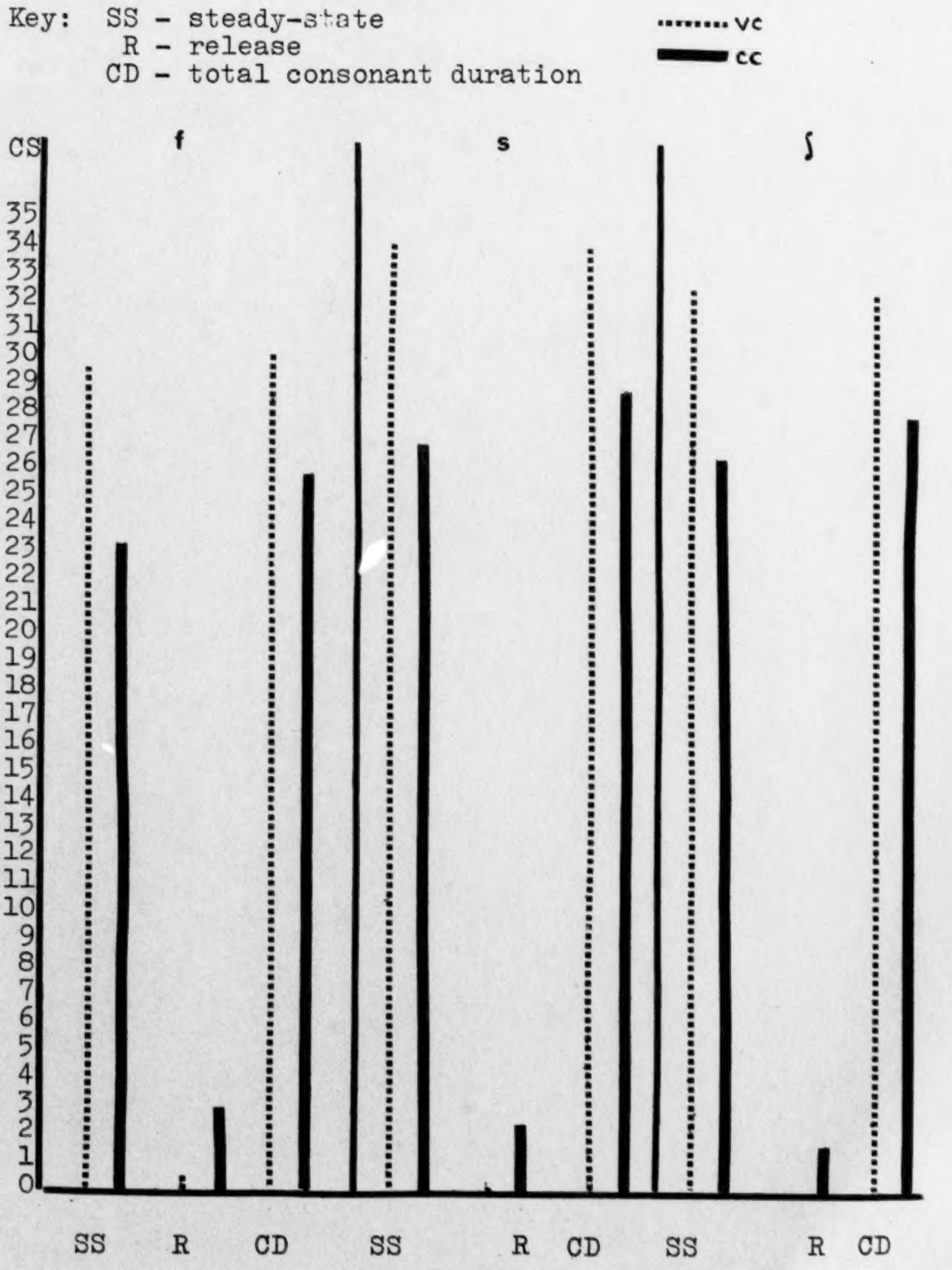
DURATION OF STEADY-STATE AND RELEASE OF FRENCH STOPS



DURATION OF STEADY-STATE AND RELEASE OF FRENCH STOPS



DURATION OF STEADY-STATE AND RELEASE OF FRENCH FRICATIVES



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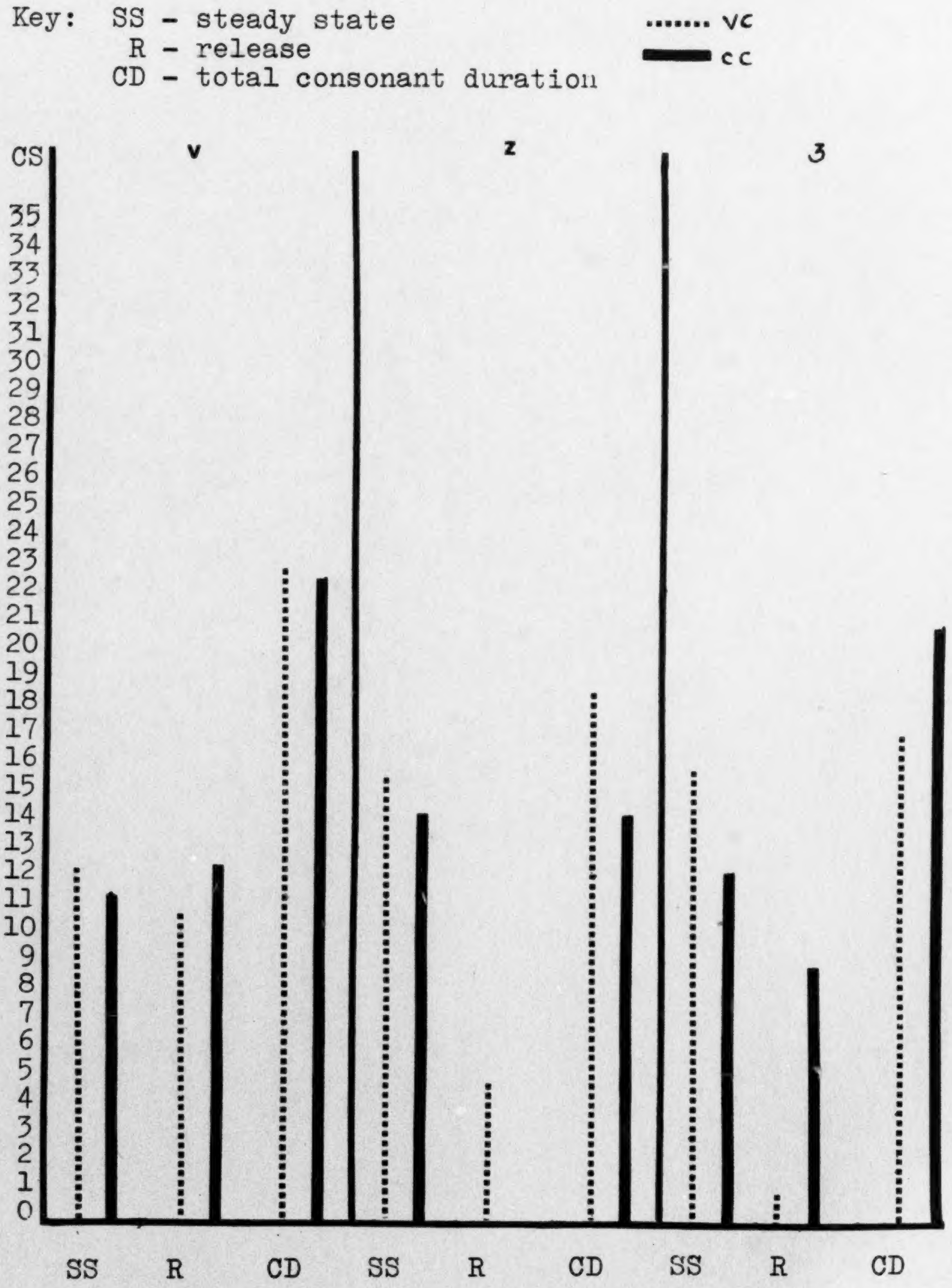
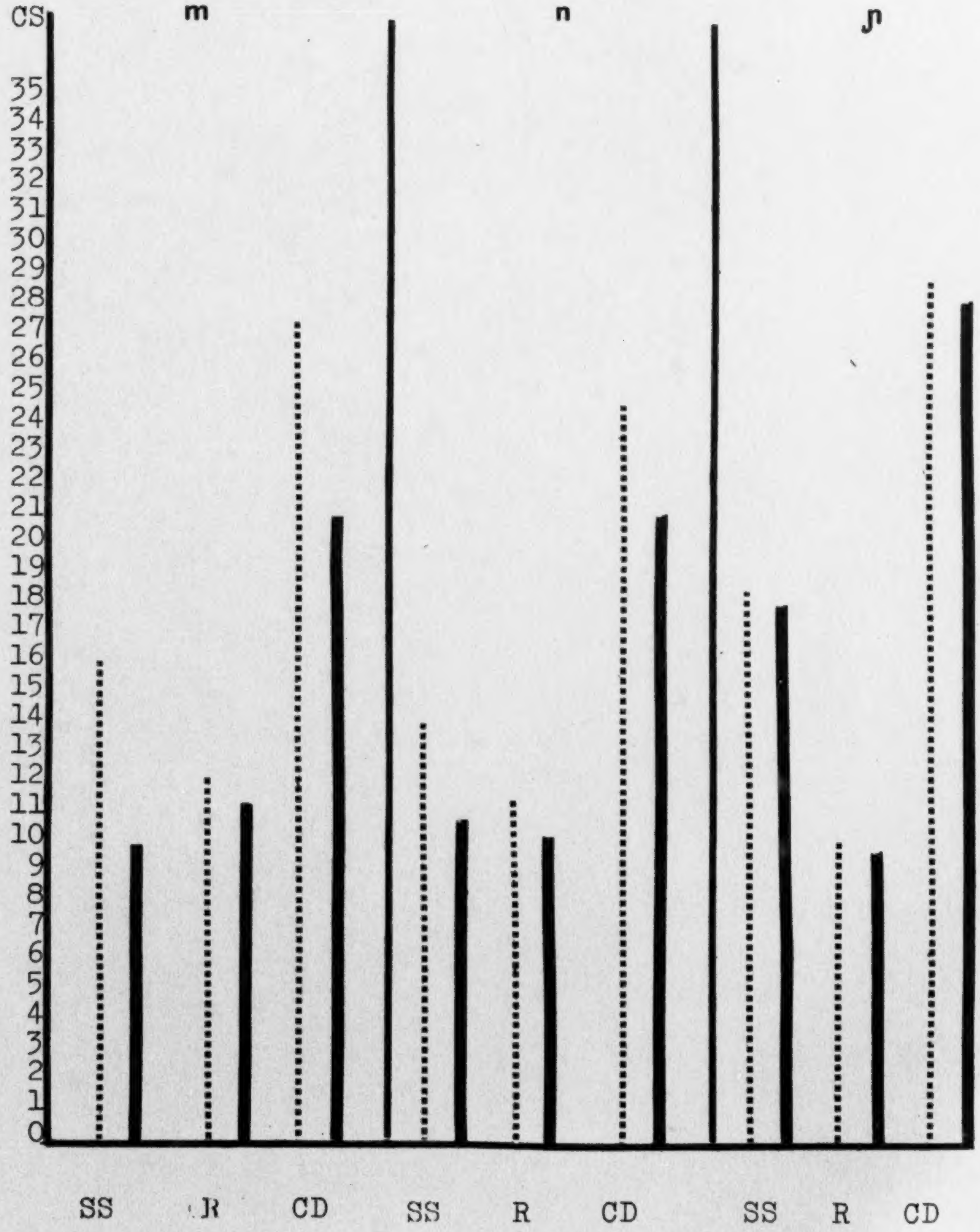


DURATION OF STEADY-STATE AND RELEASE OF FRENCH NASALS

Key: SS - steady state
R - release
CD - total consonant duration

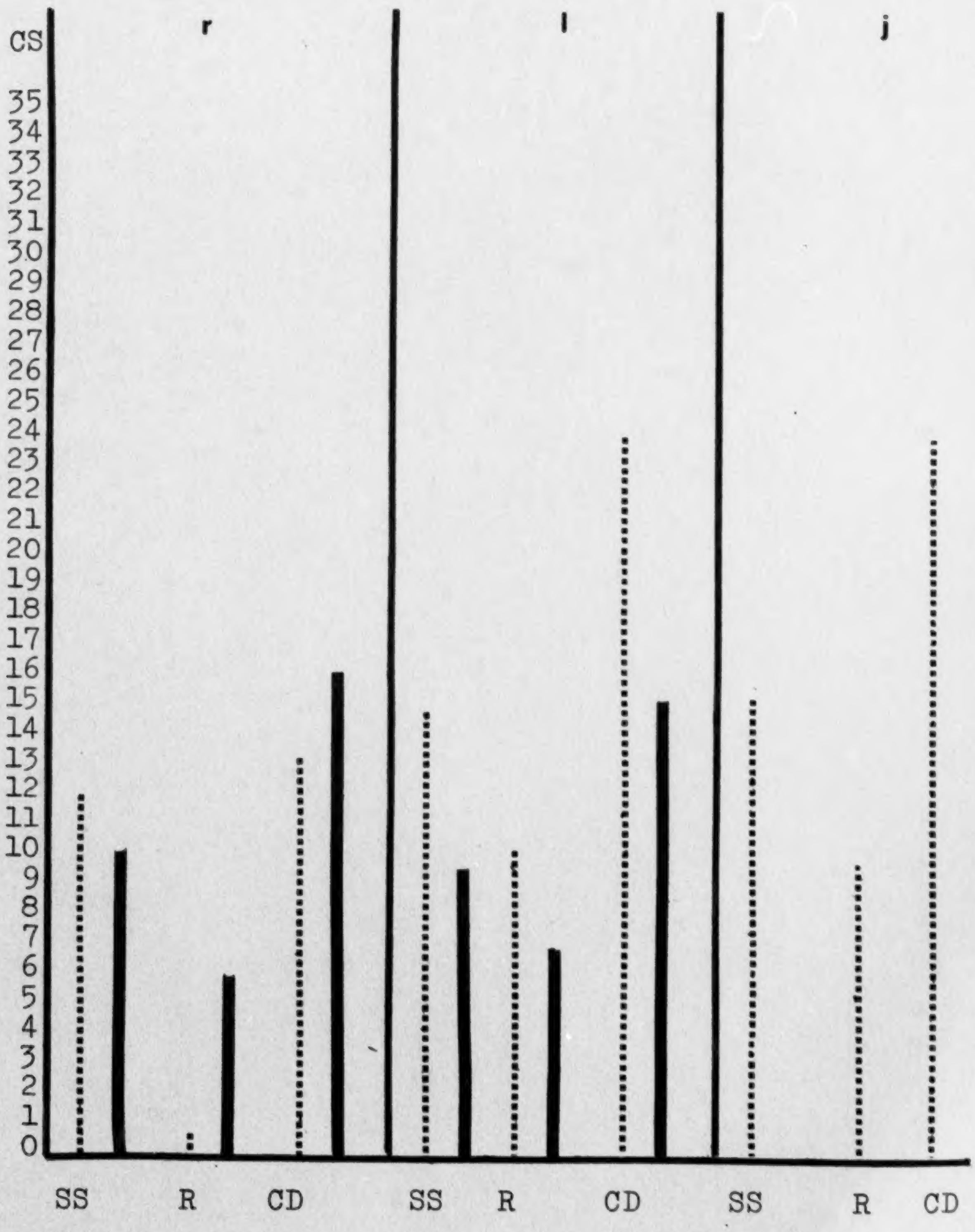
······ vc
▬ cc



DURATION OF STEADY-STATE AND RELEASE OF FRENCH LIQUIDS

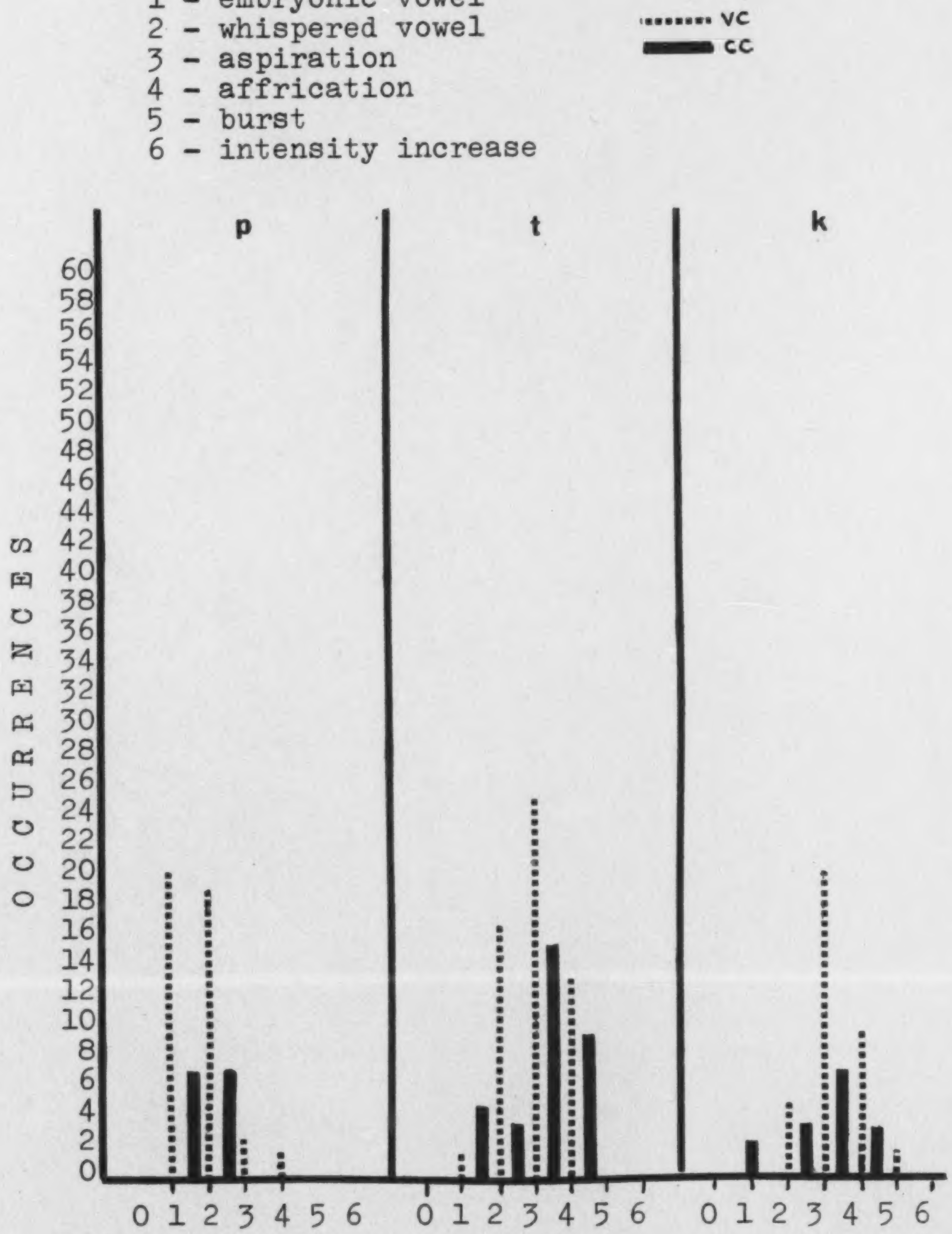
Key: SS - steady state
R - release
CD - total consonant duration

······· vc
▬ cc



DISTRIBUTION OF RELEASE TYPES FOR FRENCH STOPS

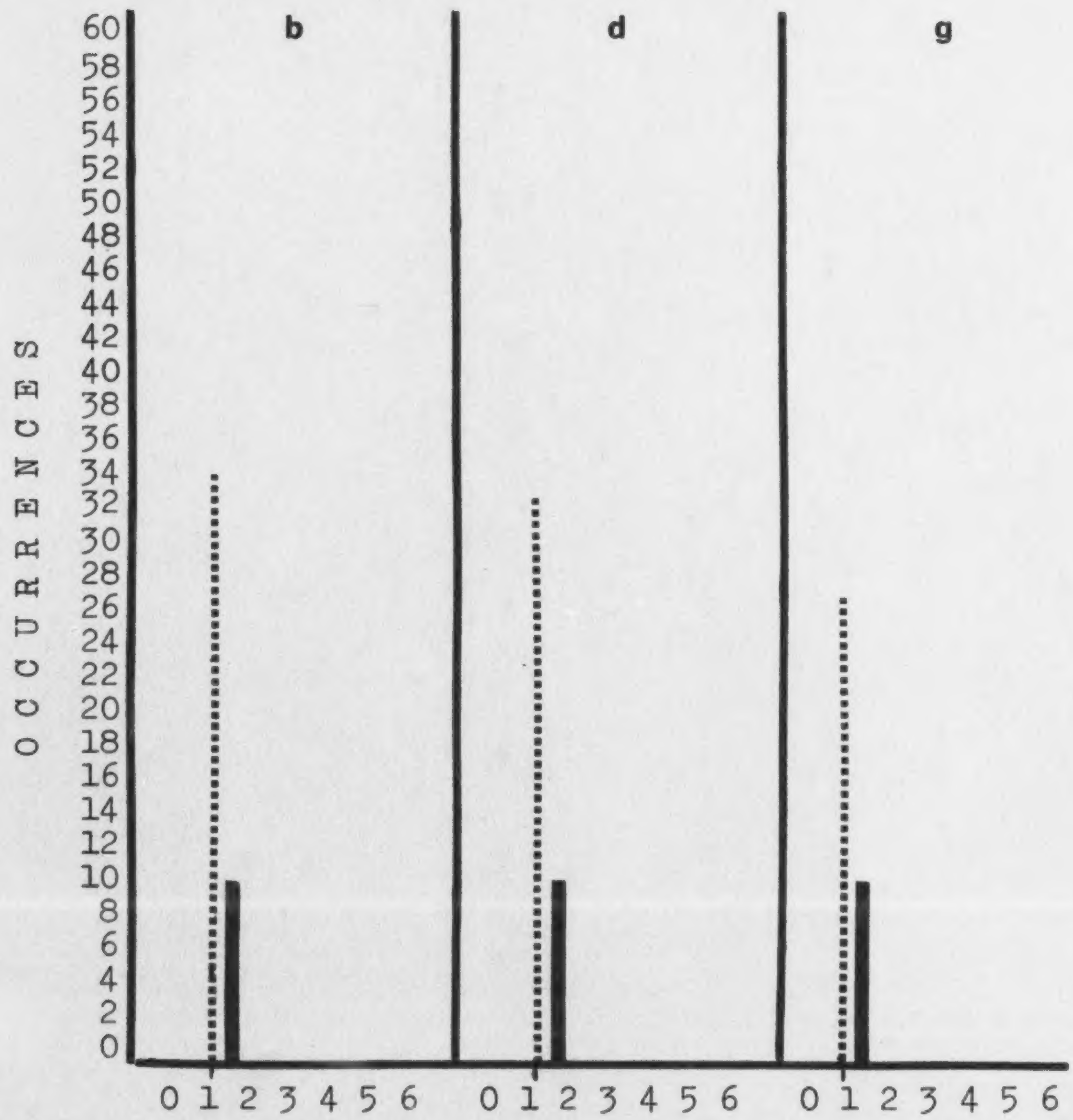
Key: 0 - no release
1 - embryonic vowel
2 - whispered vowel
3 - aspiration
4 - affrication
5 - burst
6 - intensity increase



DISTRIBUTION OF RELEASE TYPES FOR FRENCH STOPS

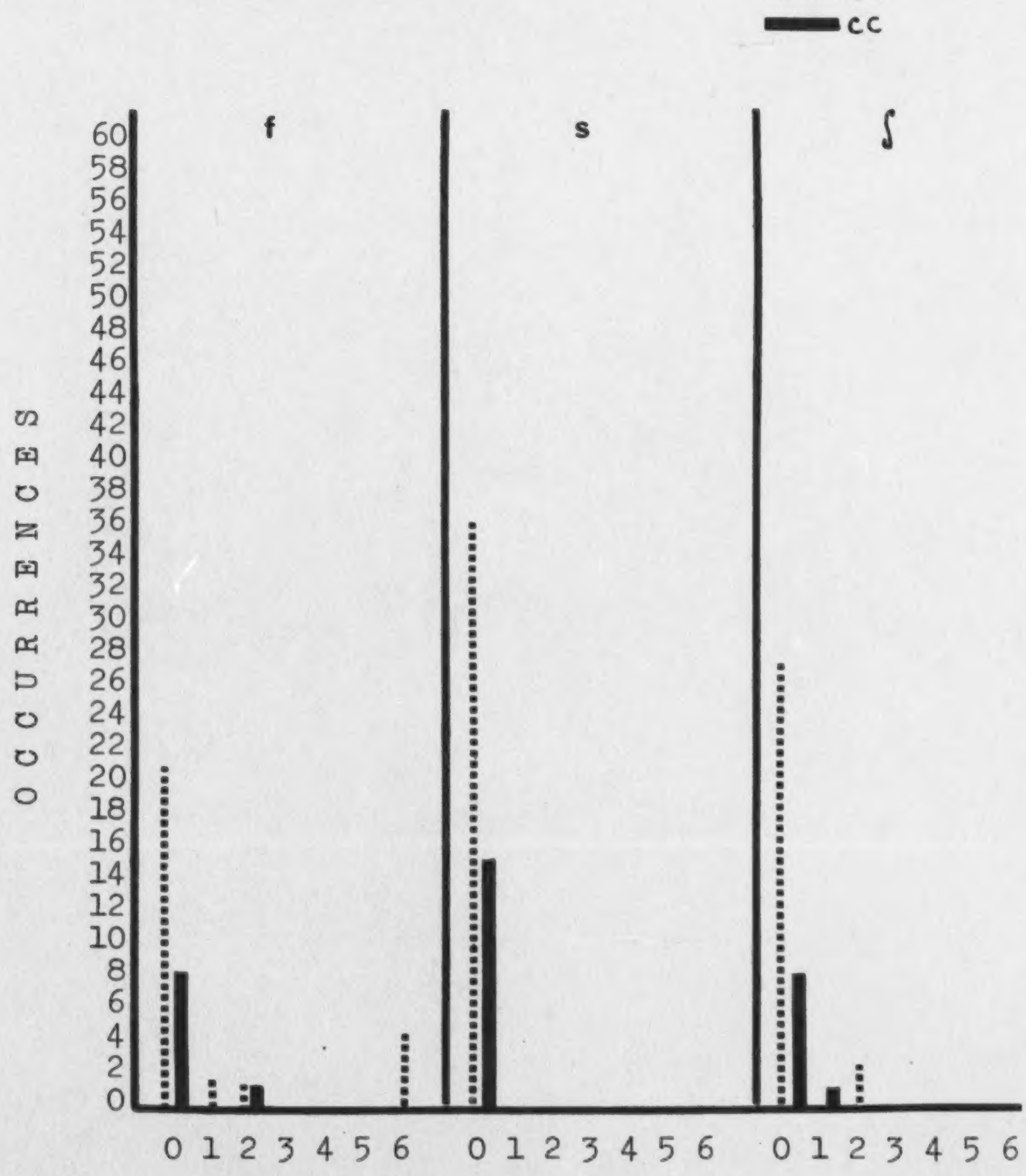
Key:
0 - no release
1 - embryonic vowel
2 - whispered vowel
3 - aspiration
4 - affrication
5 - burst
6 - intensity increase

········ vc
▬ cc



DISTRIBUTION OF RELEASE TYPES FOR FRENCH FRICATIVES

Key:
0 - no release
1 - embryonic vowel
2 - whispered vowel
3 - aspiration
4 - affrication
5 - burst
6 - intensity increase



DISTRIBUTION OF RELEASE TYPES FOR FRENCH FRICATIVES

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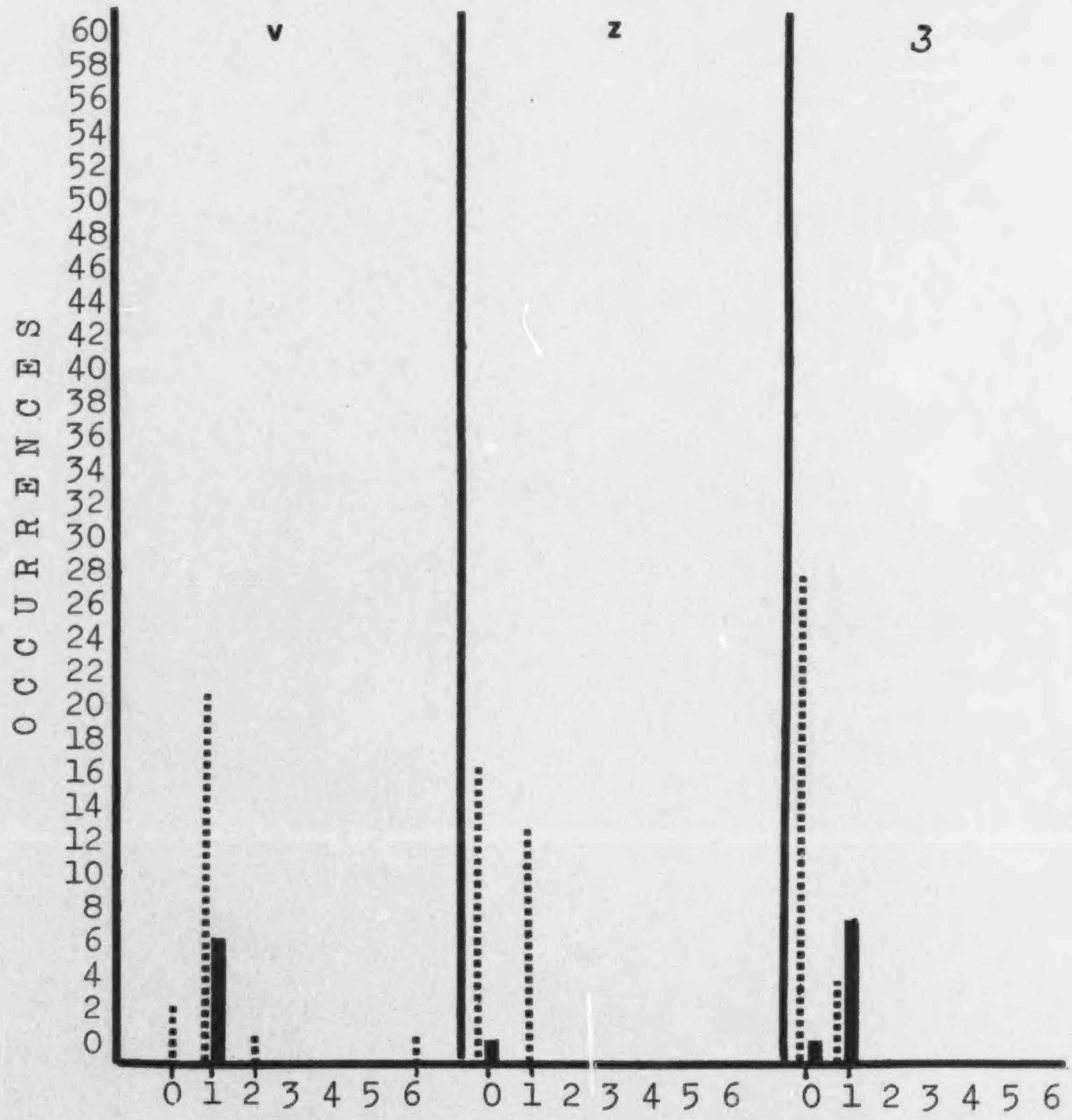
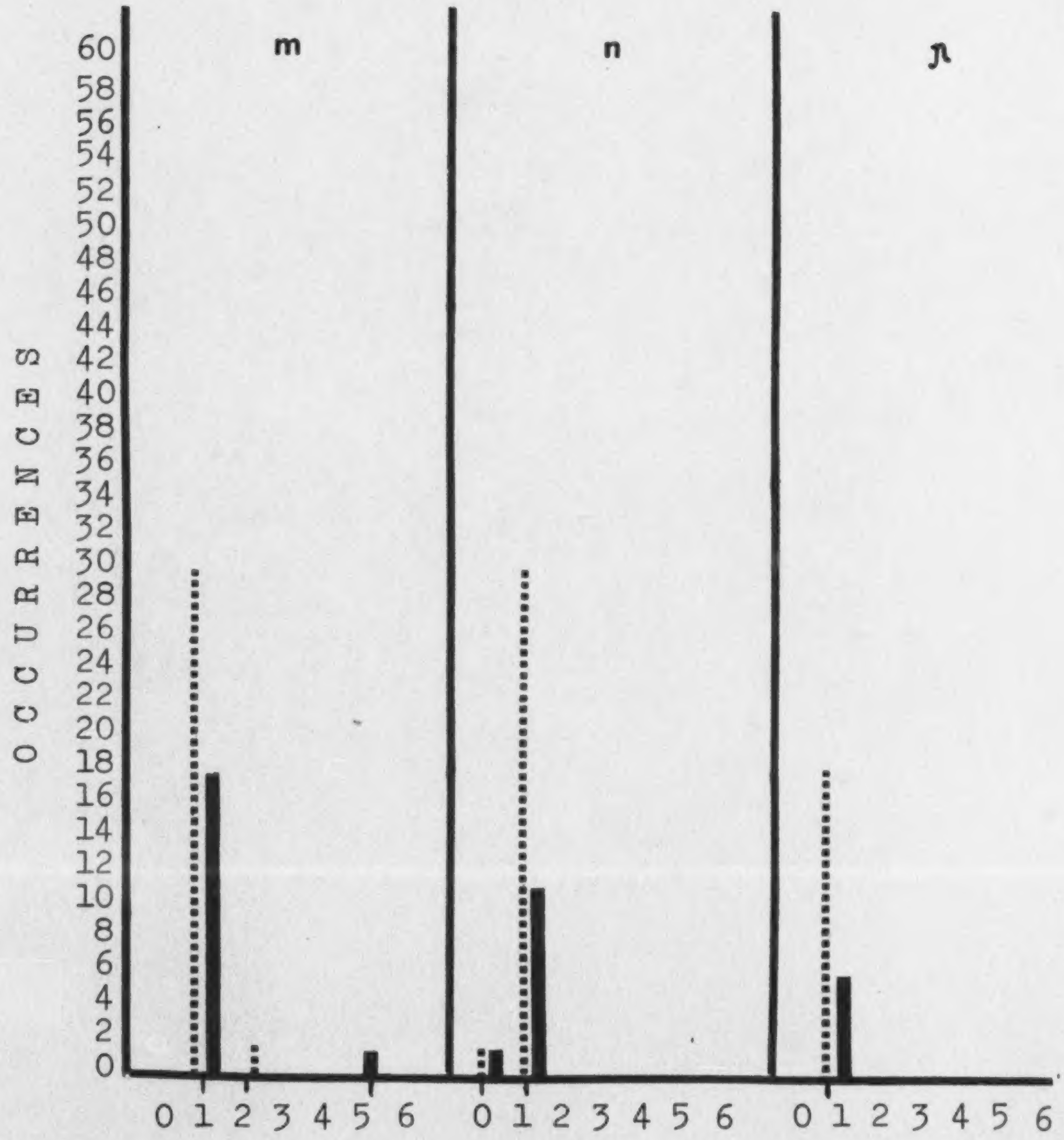


DISTRIBUTION OF RELEASE TYPES FOR FRENCH NASALS

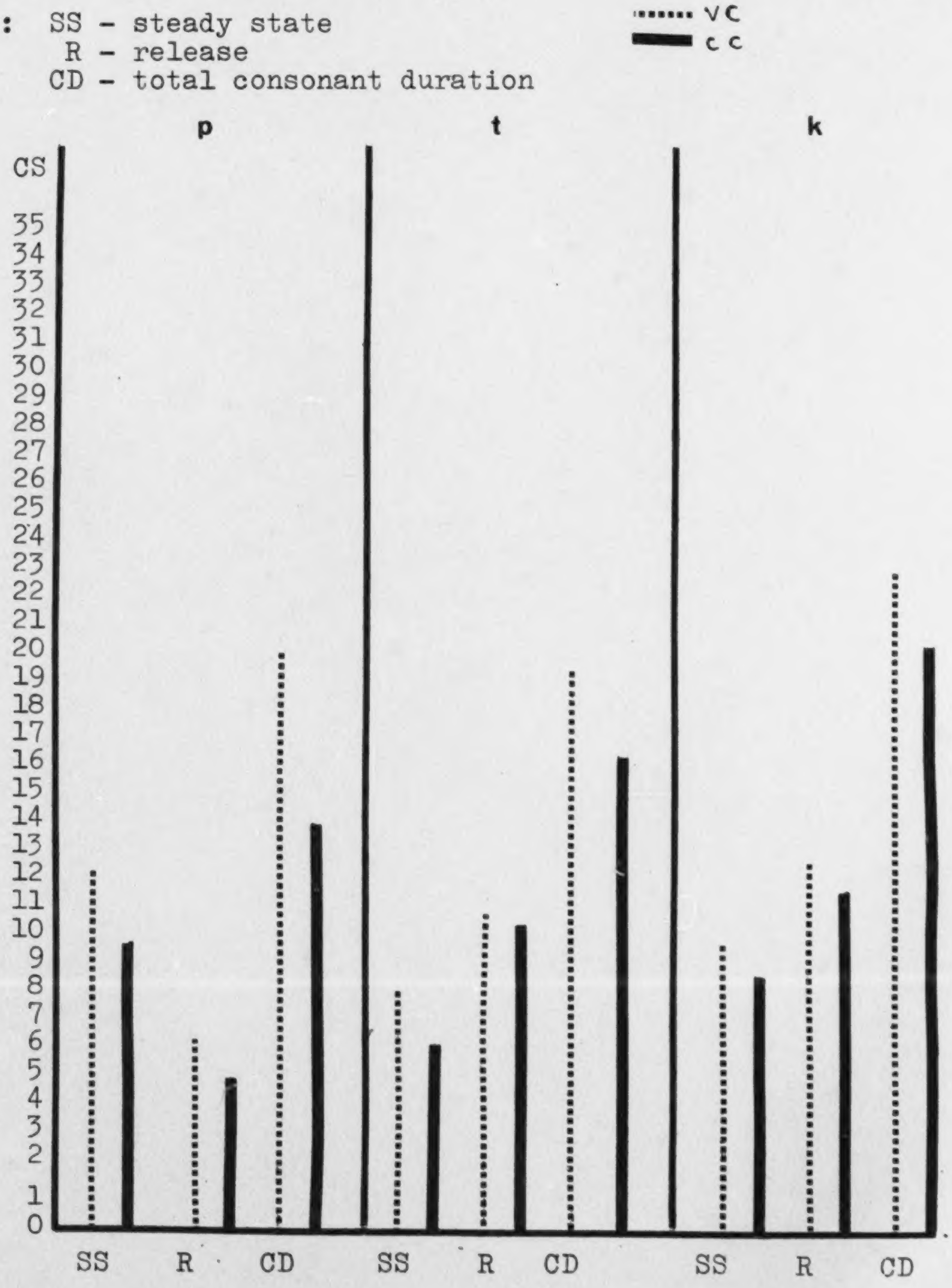
Key: 0 - no release
1 - embryonic vowel
2 - whispered vowel
3 - aspiration
4 - affrication
5 - burst
6 - intensity increase

······ vc
▬ cc



DURATION OF STEADY-STATE AND RELEASE OF AMERICAN STOPS

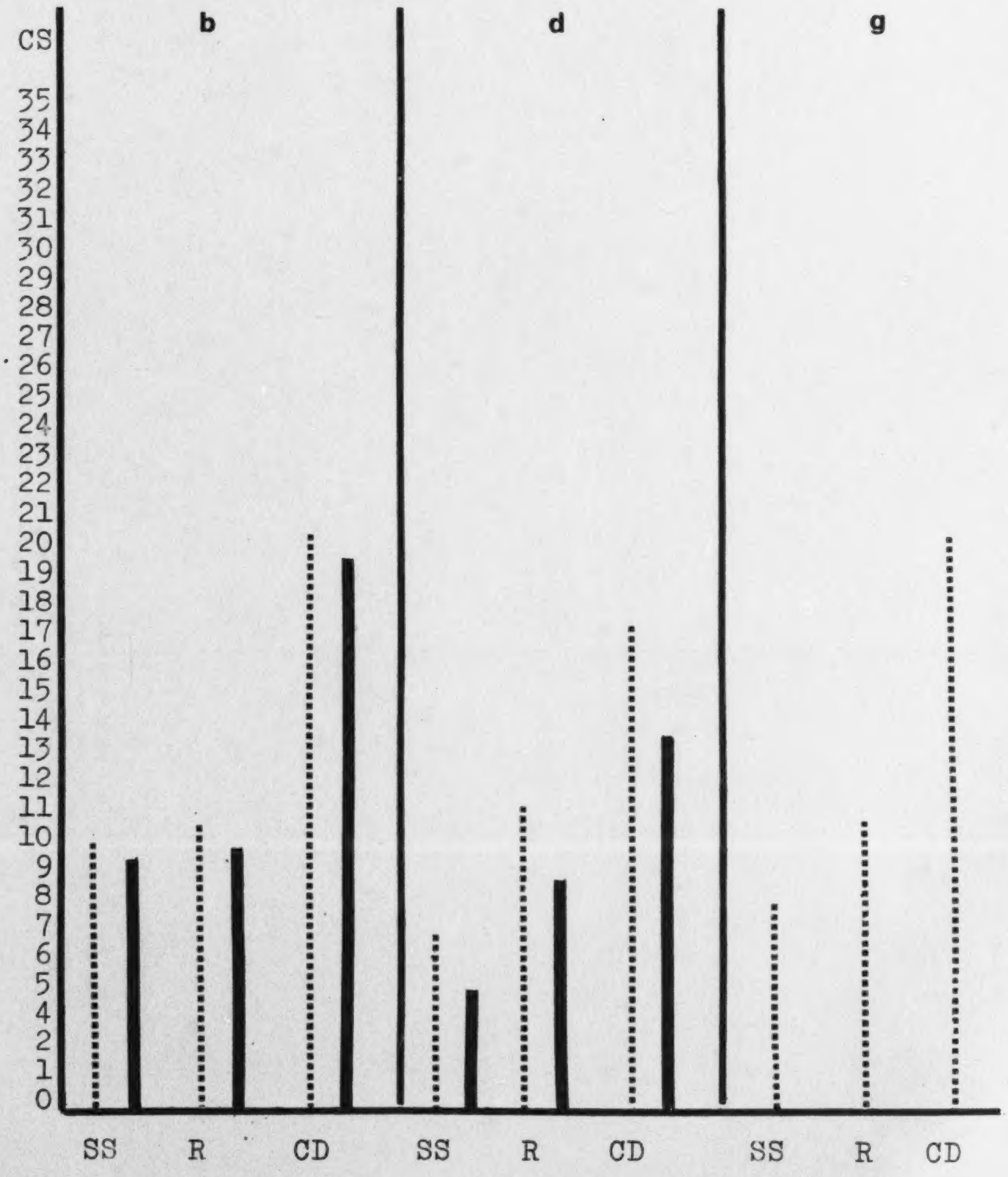
Key: SS - steady state
R - release
CD - total consonant duration



DURATION OF STEADY-STATE AND RELEASE OF AMERICAN STOPS

Key: SS - steady state
R - release
CD - total consonant duration

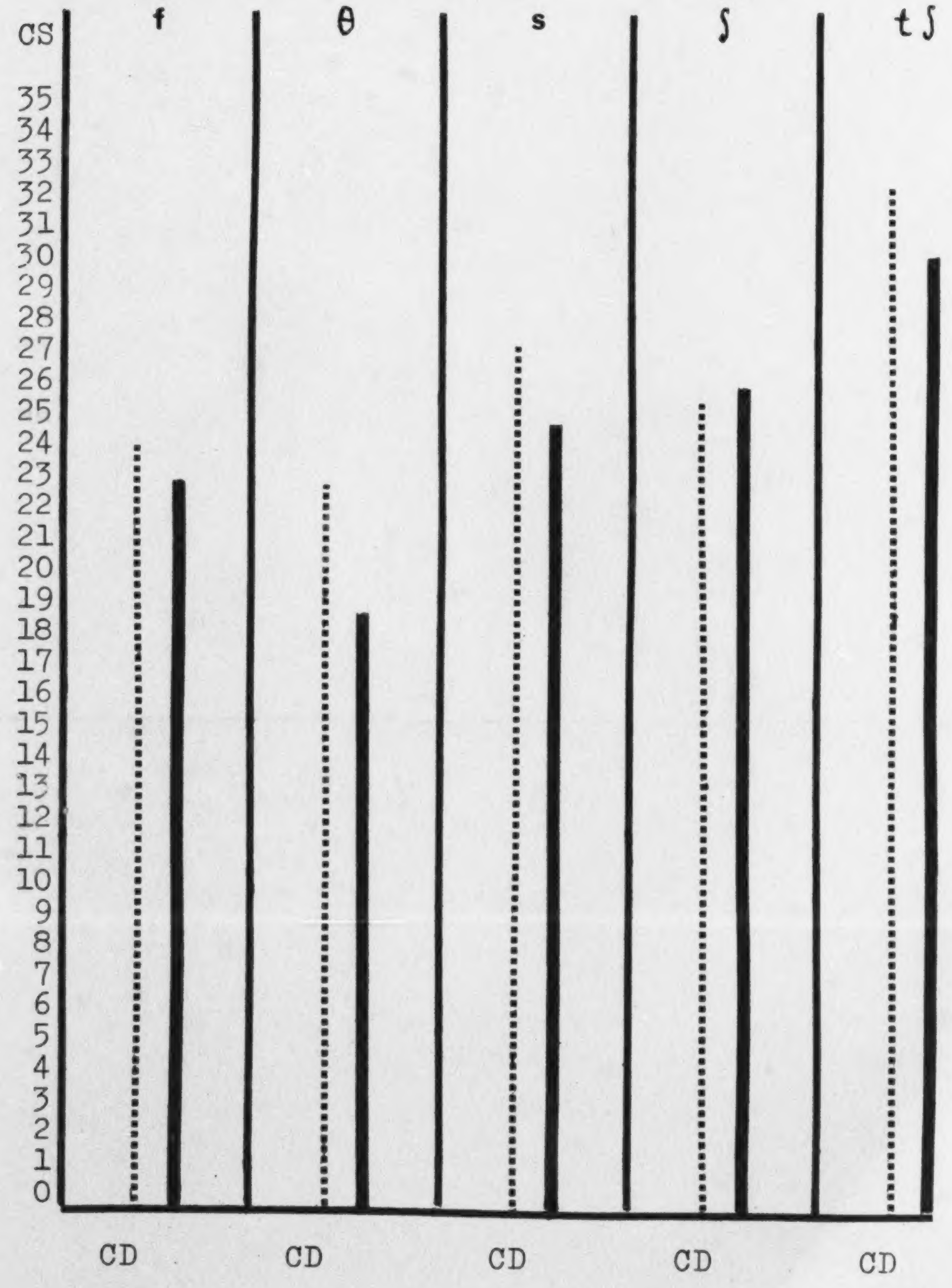
┈┈ vc
▬ cc



DURATION OF STEADY-STATE AND RELEASE OF AMERICAN FRICATIVES

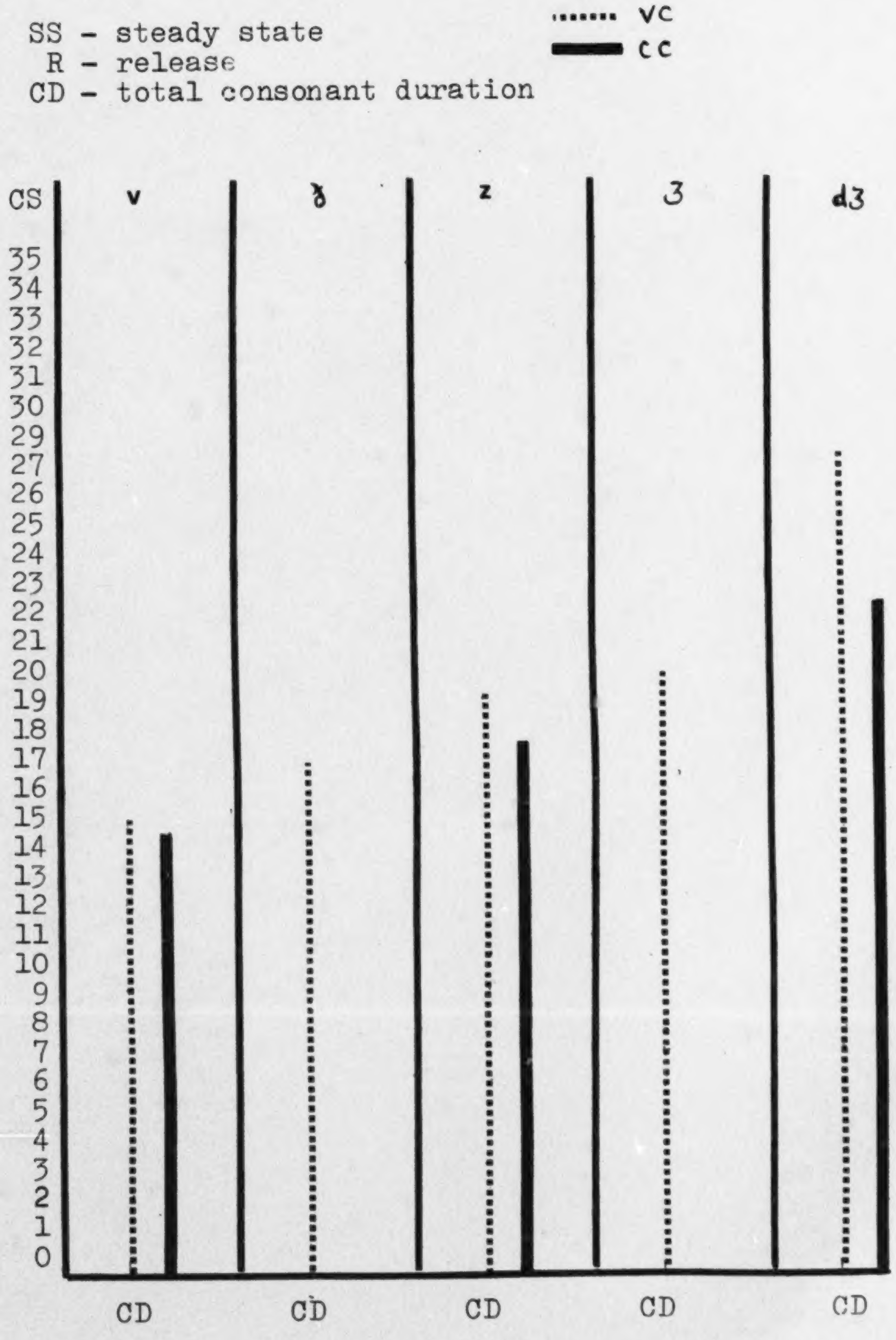
Key: SS- steady state
R - release
CD - total consonant duration

······· vc
▬ cc



DURATION OF STEADY-STATE AND RELEASE OF AMERICAN FRICATIVES

Key: SS - steady state
R - release
CD - total consonant duration



DURATION OF STEADY-STATE AND RELEASE OF AMERICAN LIQUIDS

Key: SS - steady state
R - release
CD - total consonant duration

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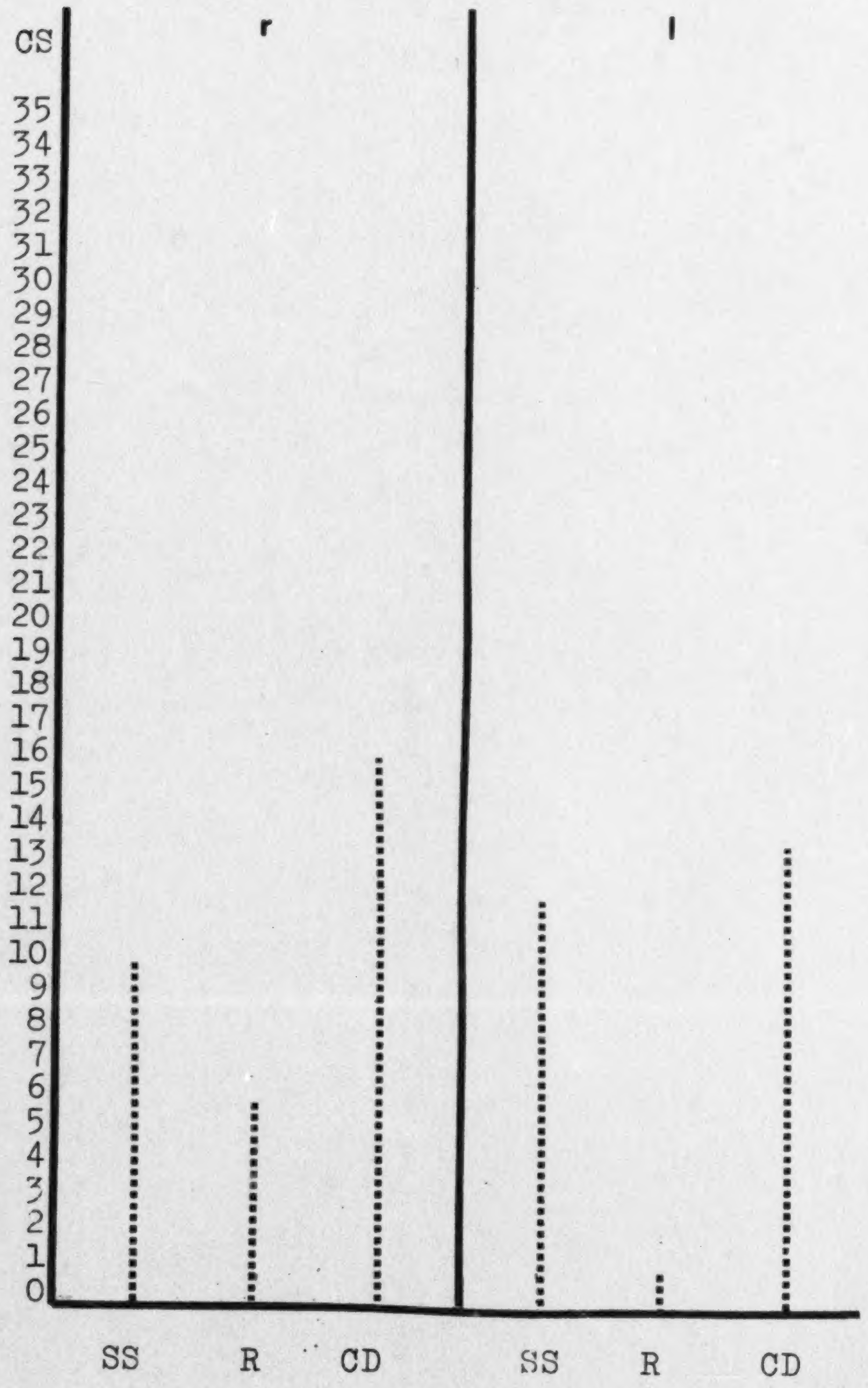
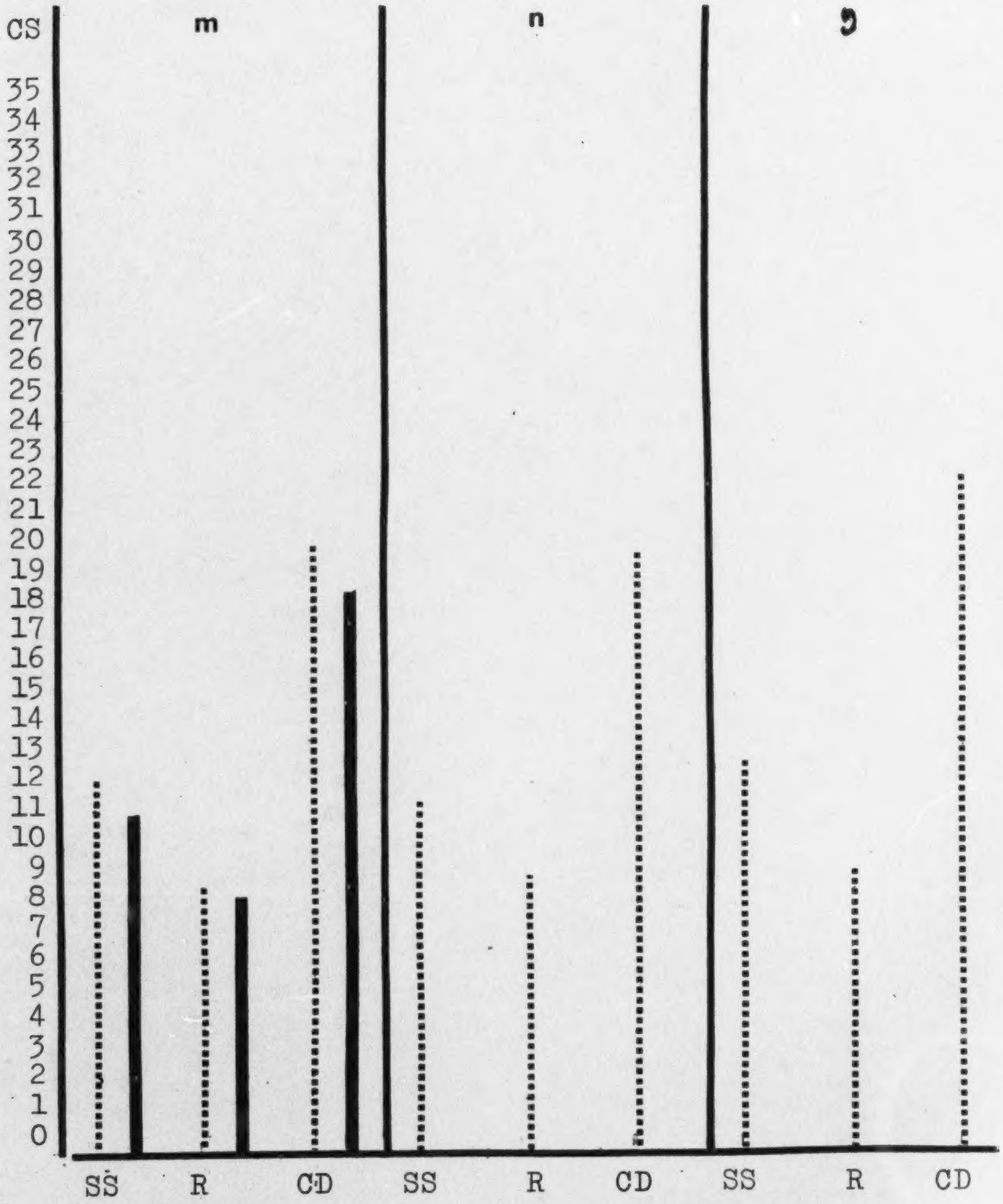


DURATION OF STEADY-STATE AND RELEASE OF AMERICAN NASALS

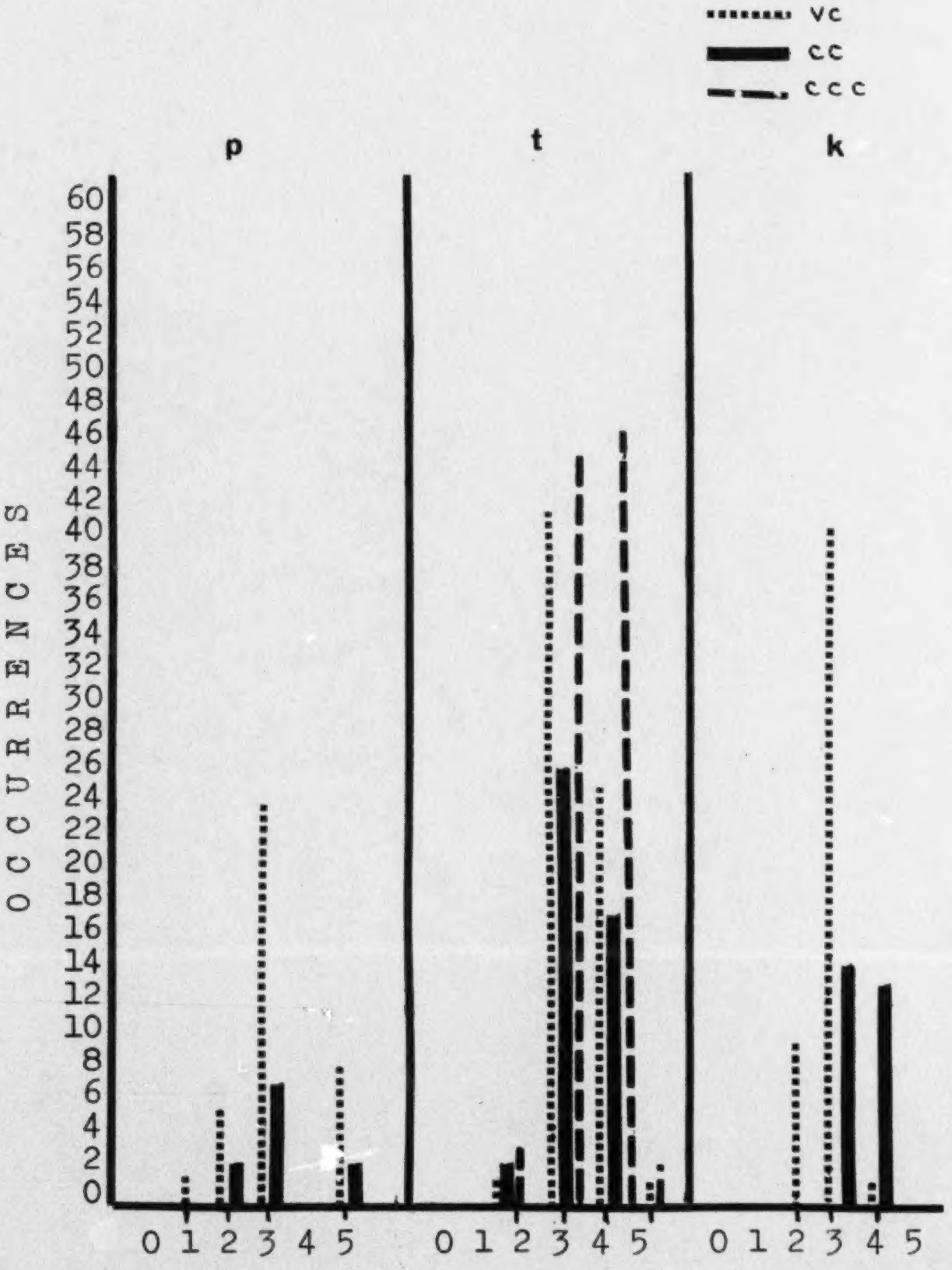
Key: SS - steady state
R - release
CD - total consonant duration

┈┈ vc
━━ cc



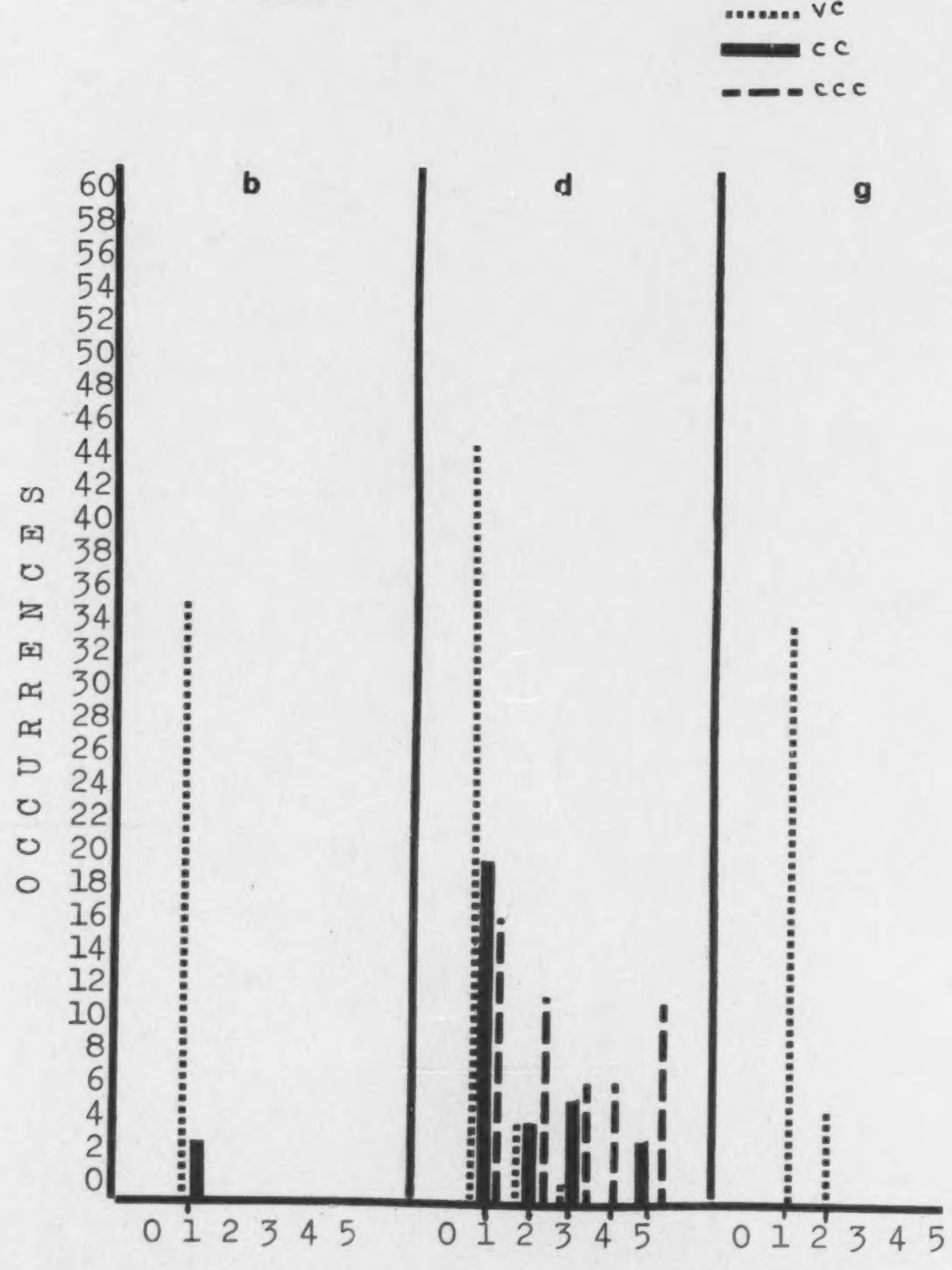
DISTRIBUTION OF RELEASE TYPES FOR AMERICAN STOPS

Key:
0 - no release
1 - embryonic vowel
2 - whispered vowel
3 - aspiration
4 - affrication
5 - burst



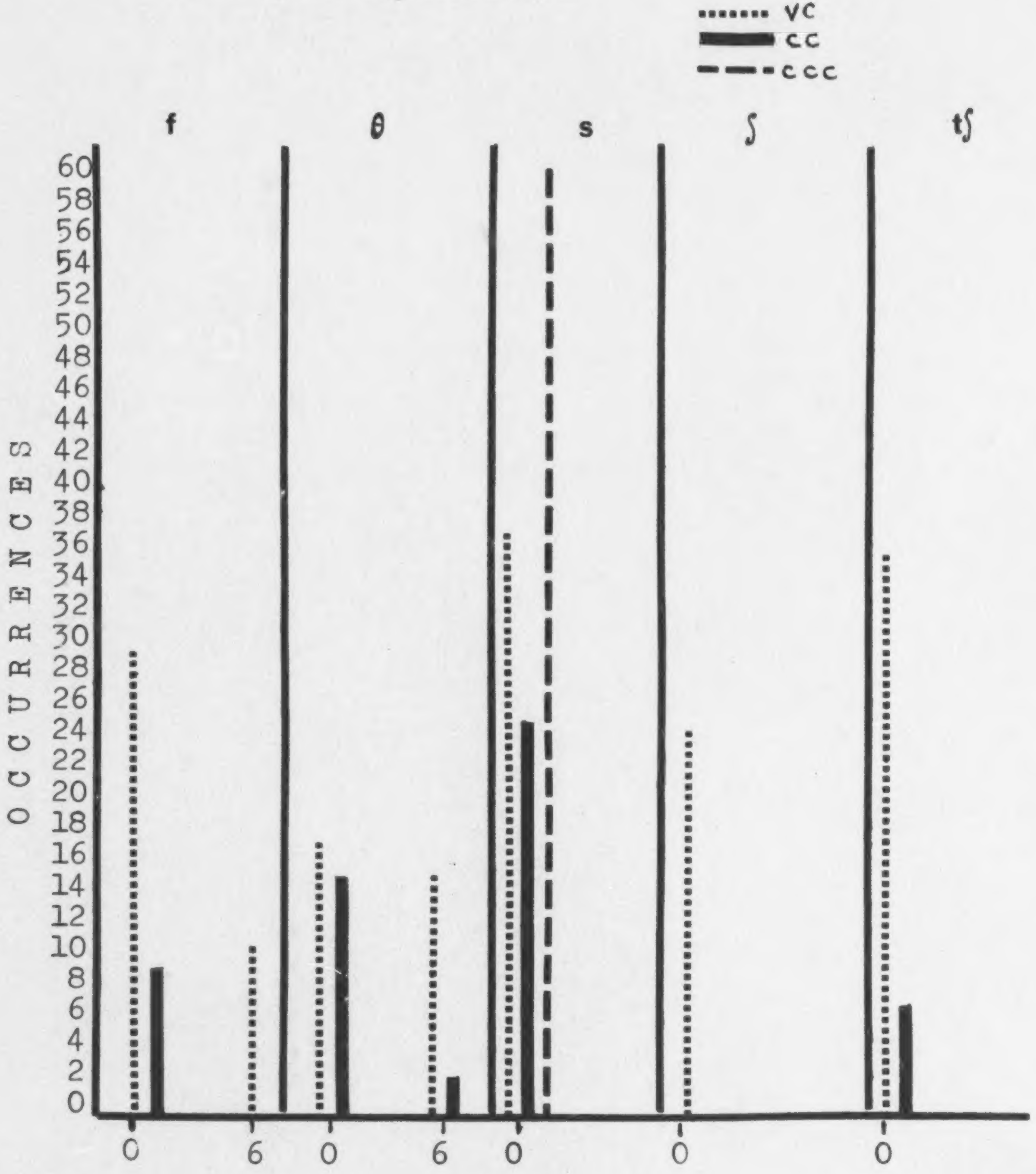
DISTRIBUTION OF RELEASE TYPES FOR AMERICAN STOPS

Key: 0 - no release
1 - embryonic vowel
2 - whispered vowel
3 - aspiration
4 - affrication
5 - burst



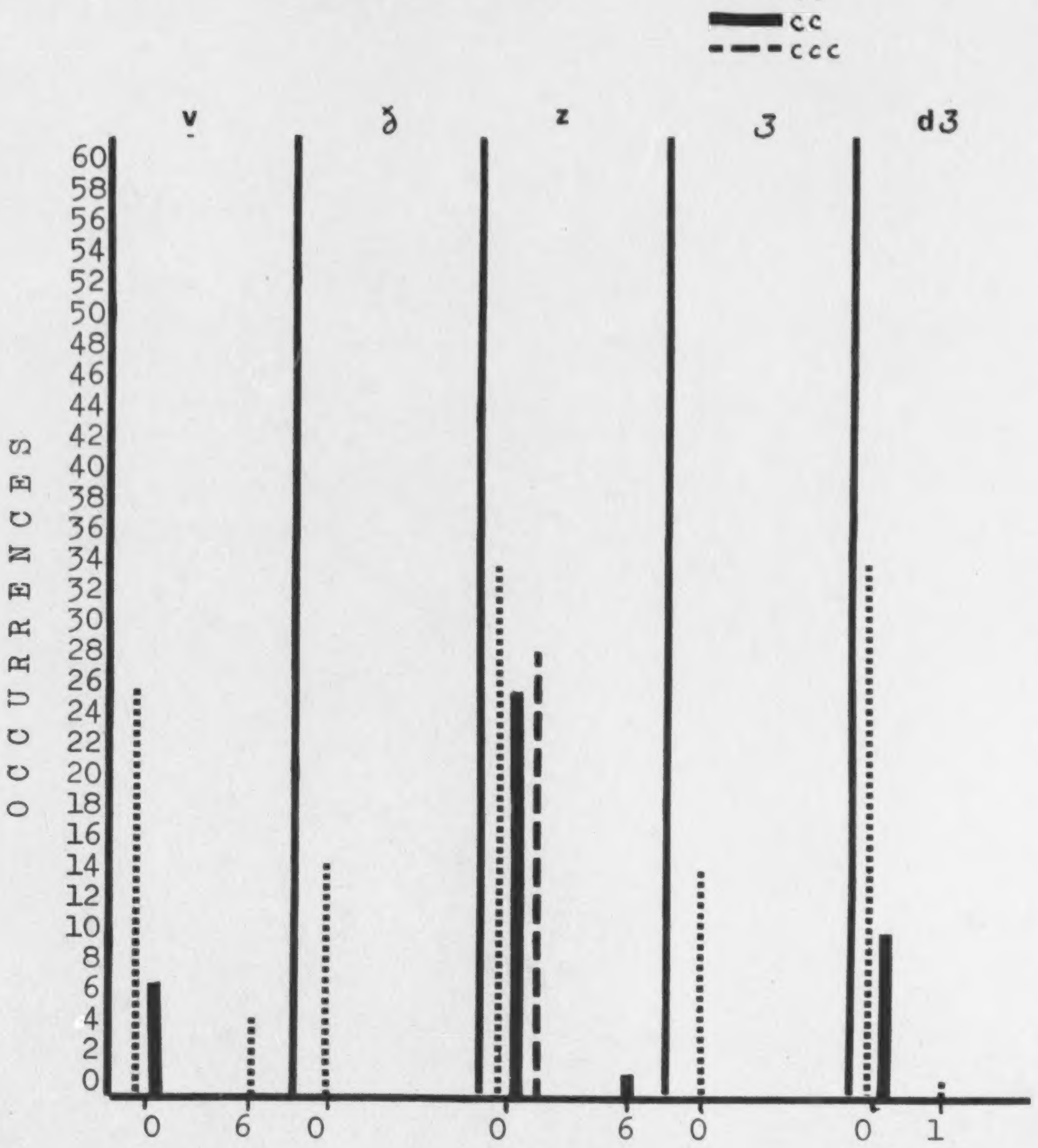
DISTRIBUTION OF RELEASE TYPES FOR AMERICAN FRICATIVES

Key: 0 - no release
6 - intensity increase



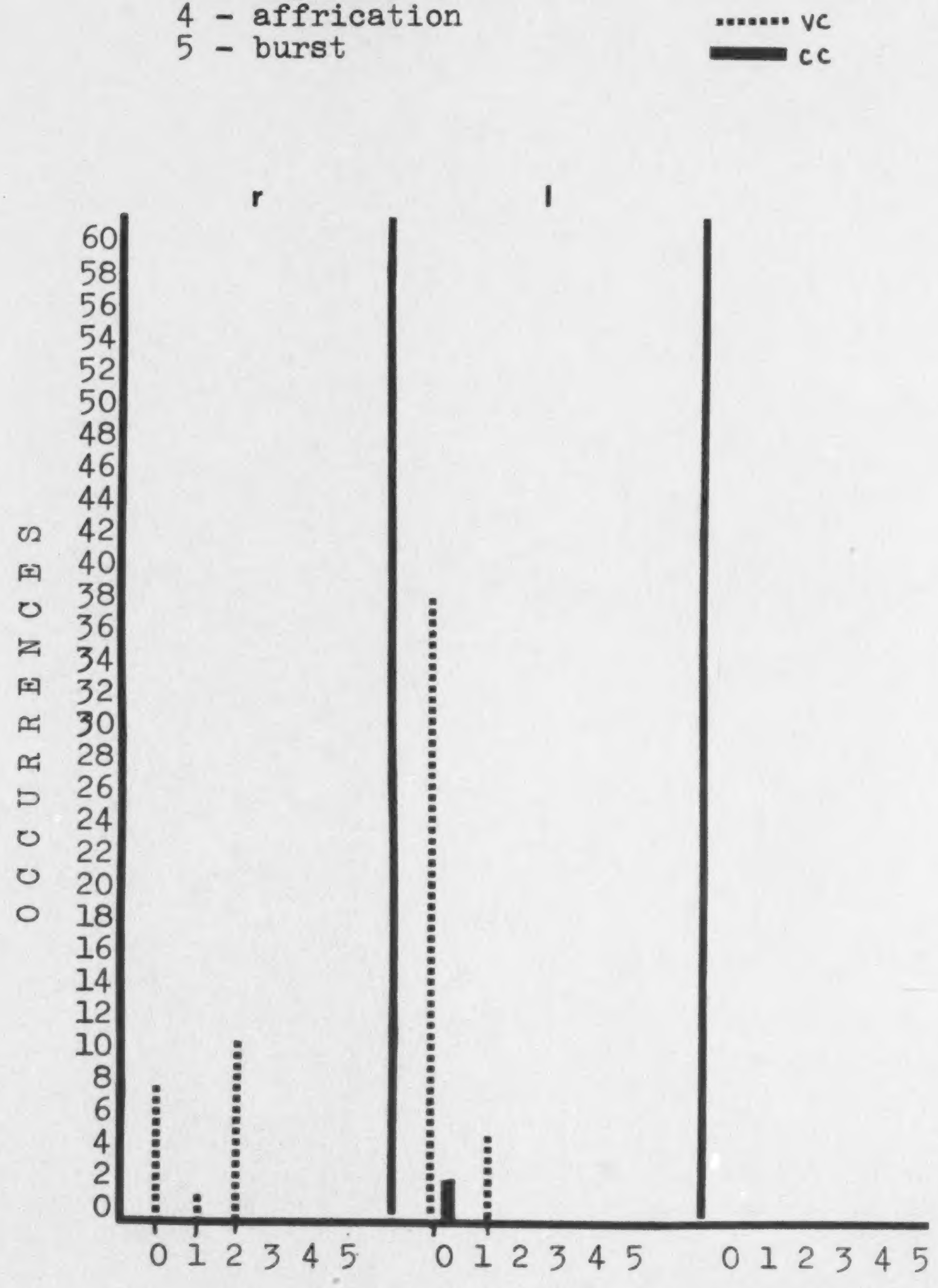
DISTRIBUTION OF RELEASE TYPES FOR AMERICAN FRICATIVES

Key: 0 - no release
1 - embryonic vowel
6 - intensity increase



DISTRIBUTION OF RELEASE TYPES FOR AMERICAN LIQUIDS

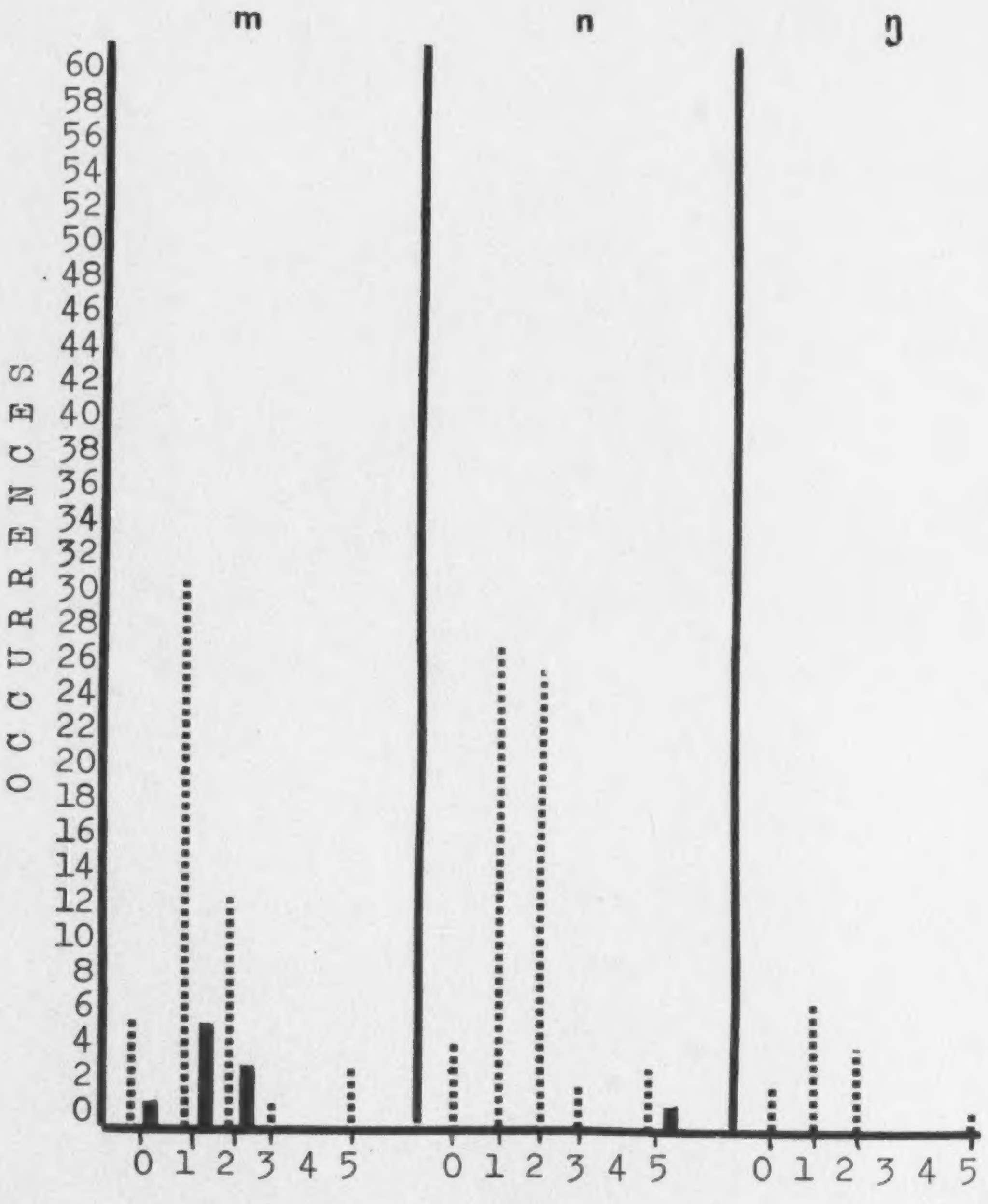
Key: 0 - no release
1 - embryonic vowel
2 - whispered vowel
3 - aspiration
4 - affrication
5 - burst



DISTRIBUTION OF RELEASE TYPES FOR AMERICAN NASALS

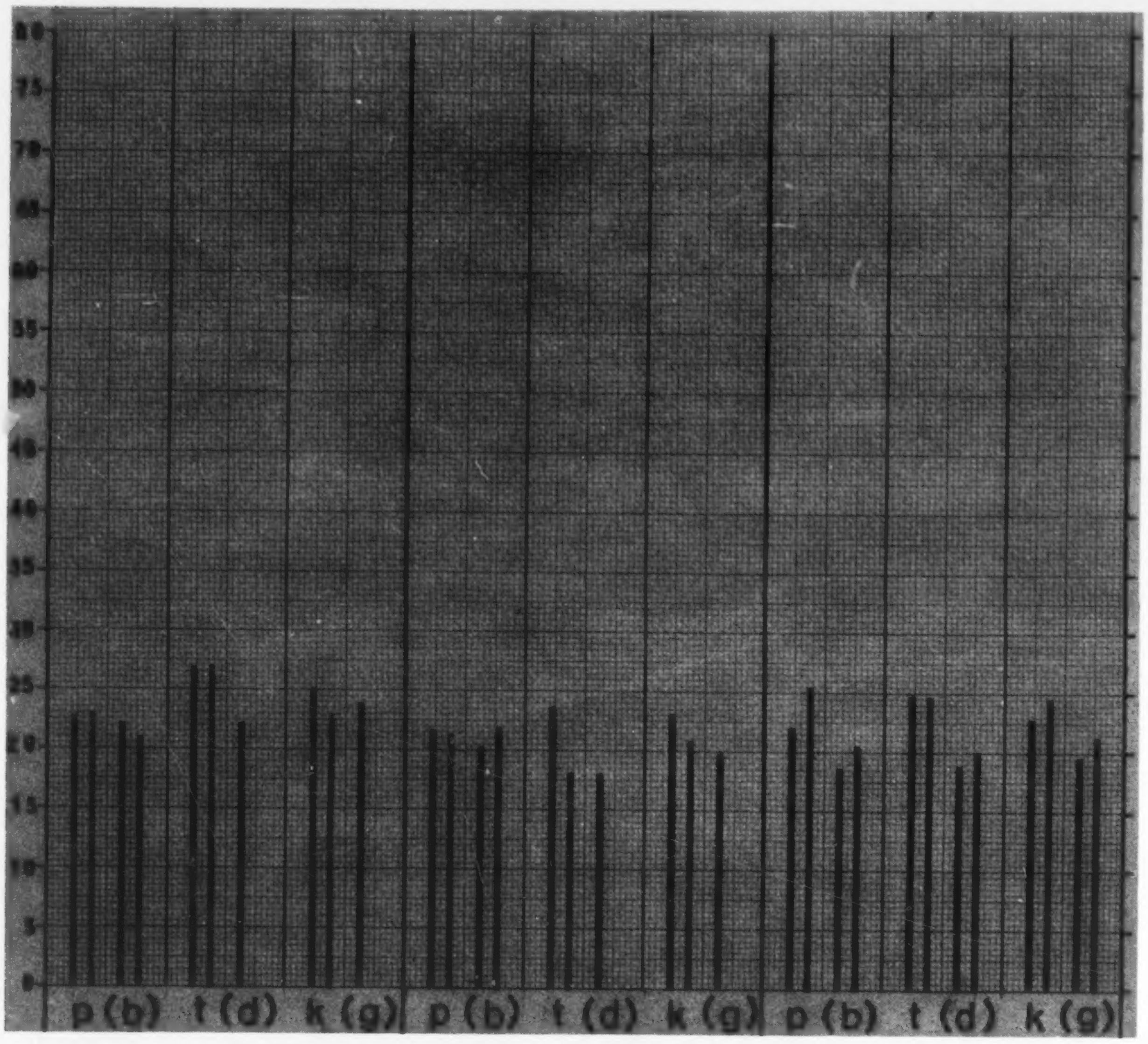
Key:
0 - no release
1 - embryonic vowel
2 - whispered vowel
3 - aspiration
4 - affrication
5 - burst

······· vc
━━━ cc



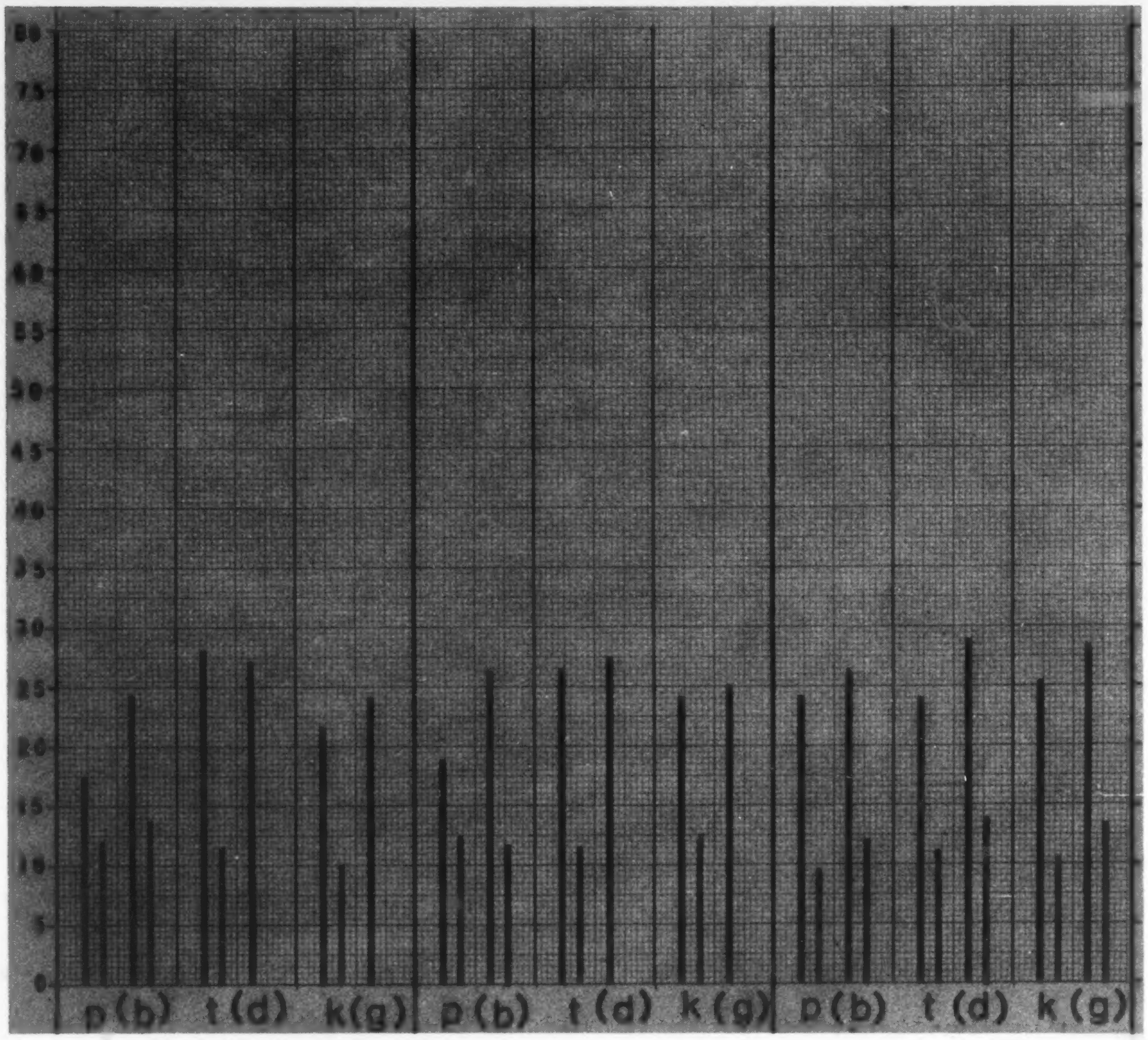
DURATION OF CONSONANT FOR GERMAN STOPS

(Broken line = after short, solid line = after long vowel)



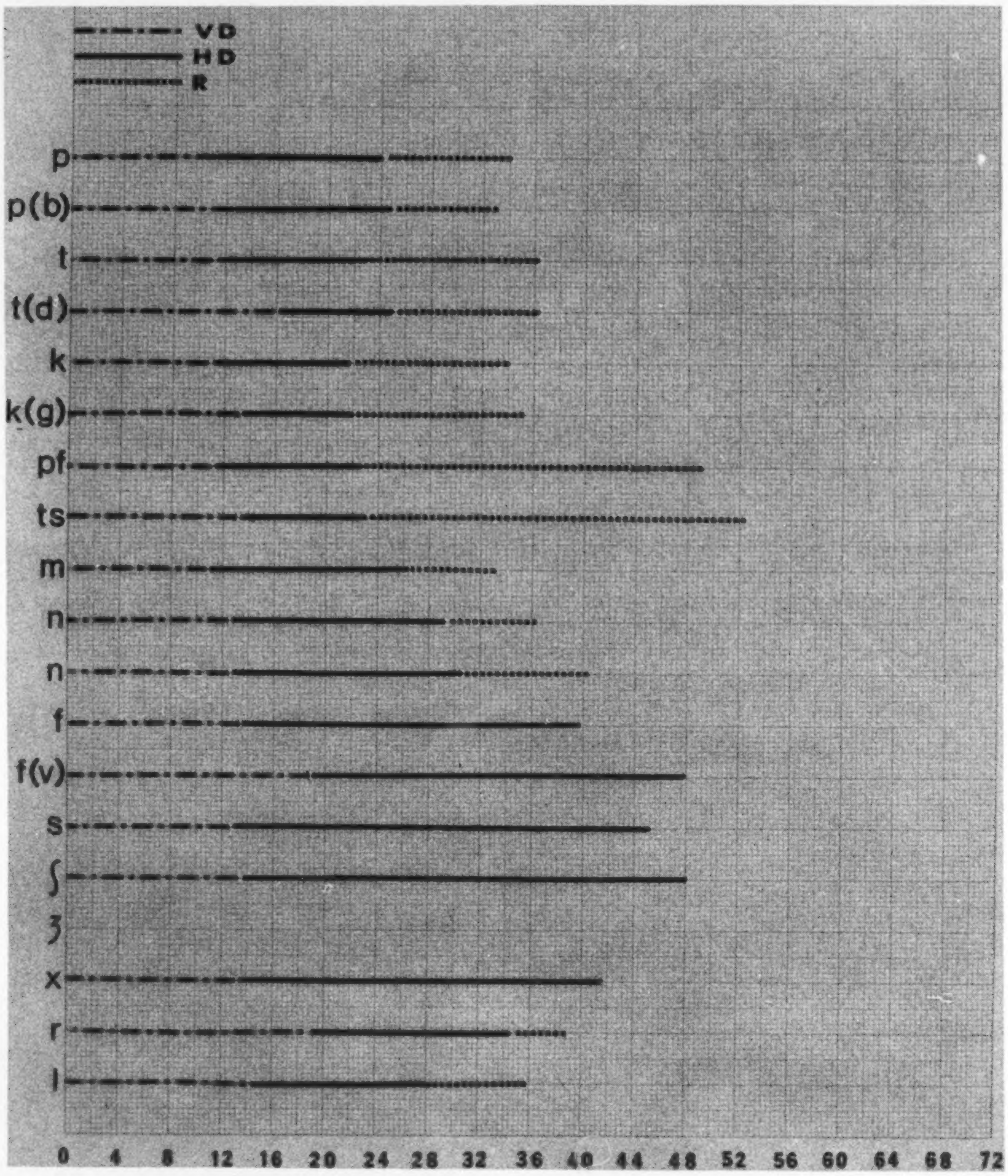
DURATION OF VOWEL FOR GERMAN STOPS

(Broken line = short, solid line = long)

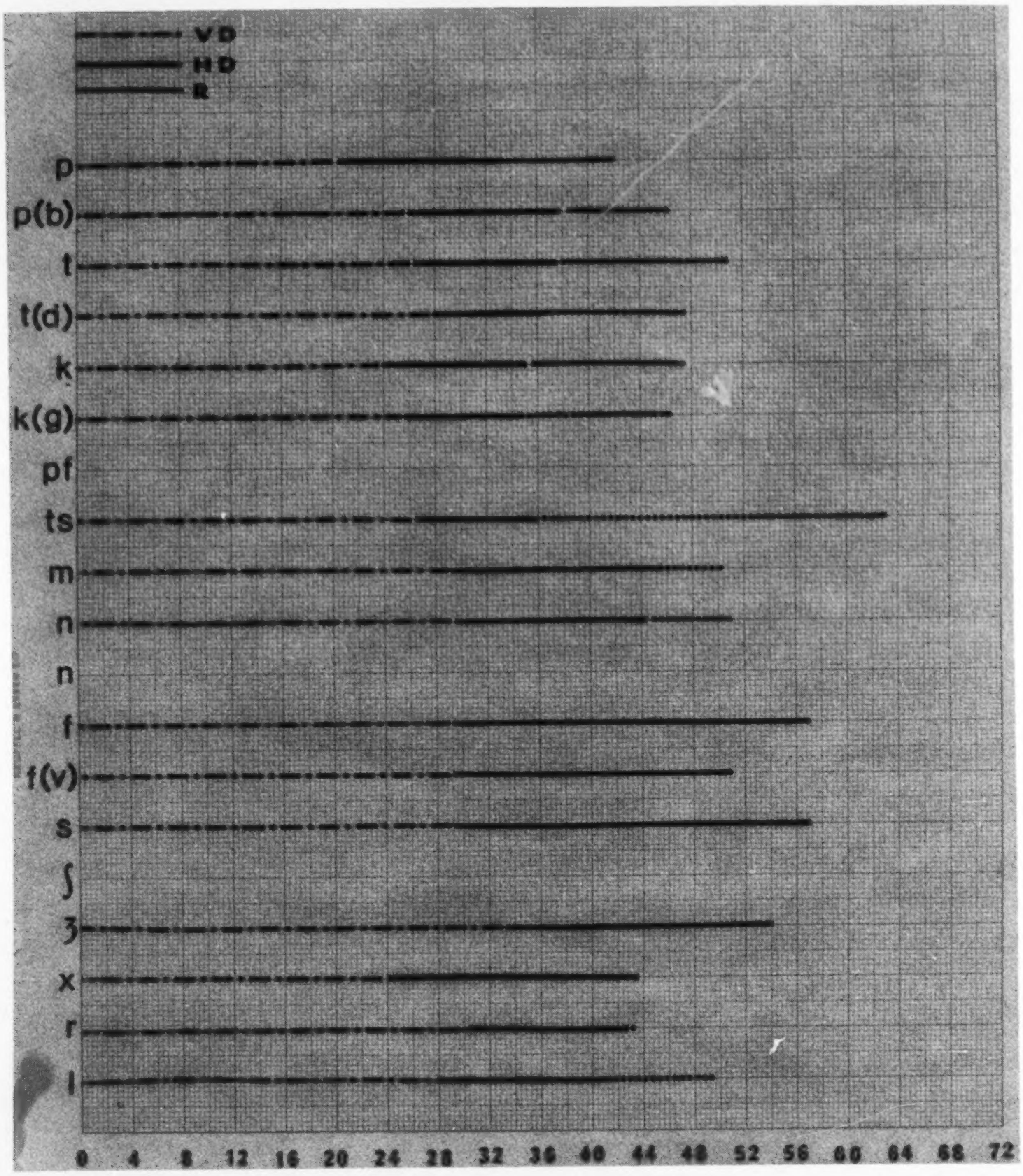


DURATION OF VOWEL(VD), CONSONANT STEADY-STATE(HD)

AND RELEASE(R) FOR GERMAN -- WITH SHORT VOWEL

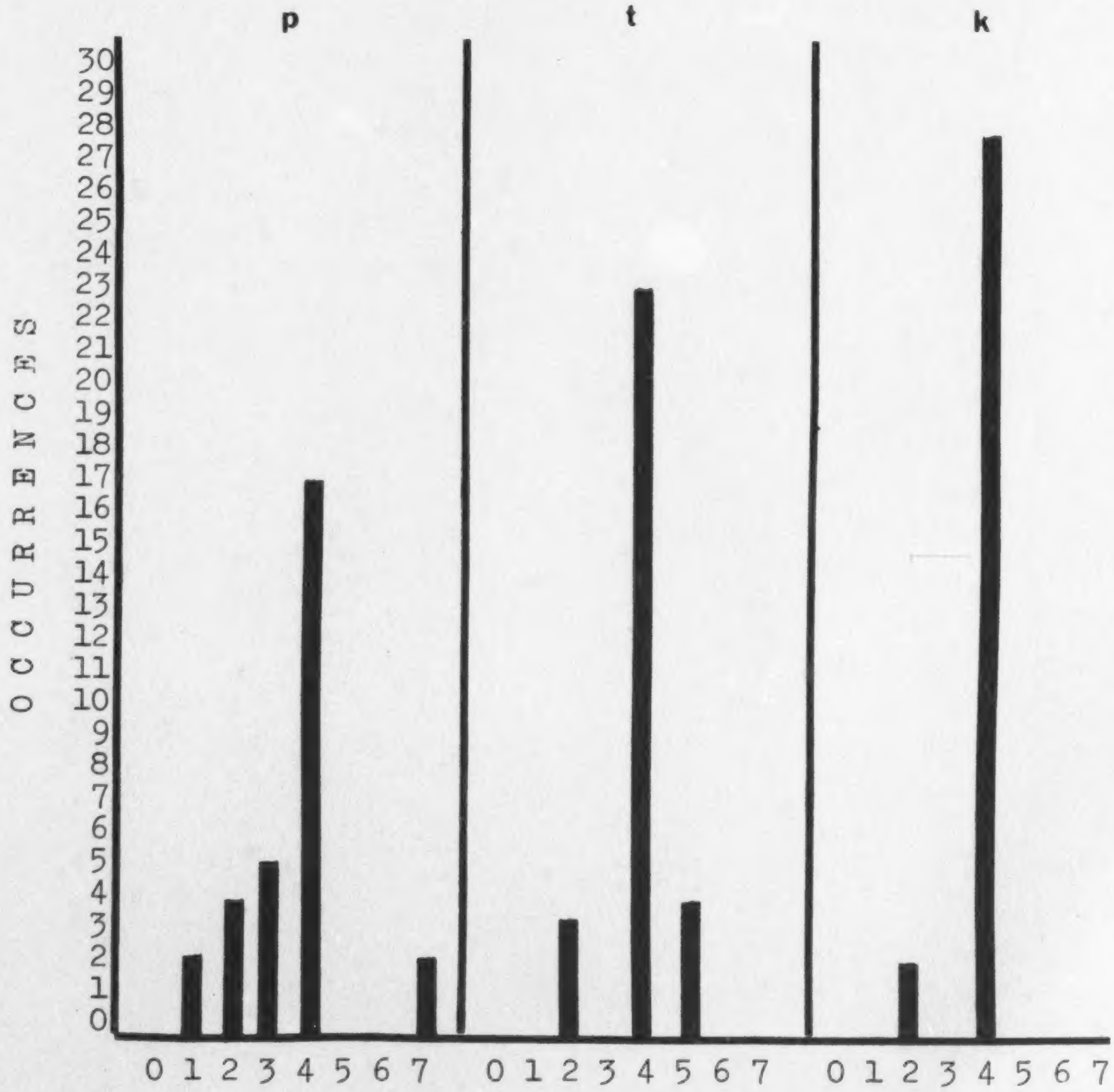


DURATION OF VOWEL(VD), CONSONANT STEADY-STATE(HD)
AND RELEASE(R) FOR GERMAN -- WITH LONG VOWEL



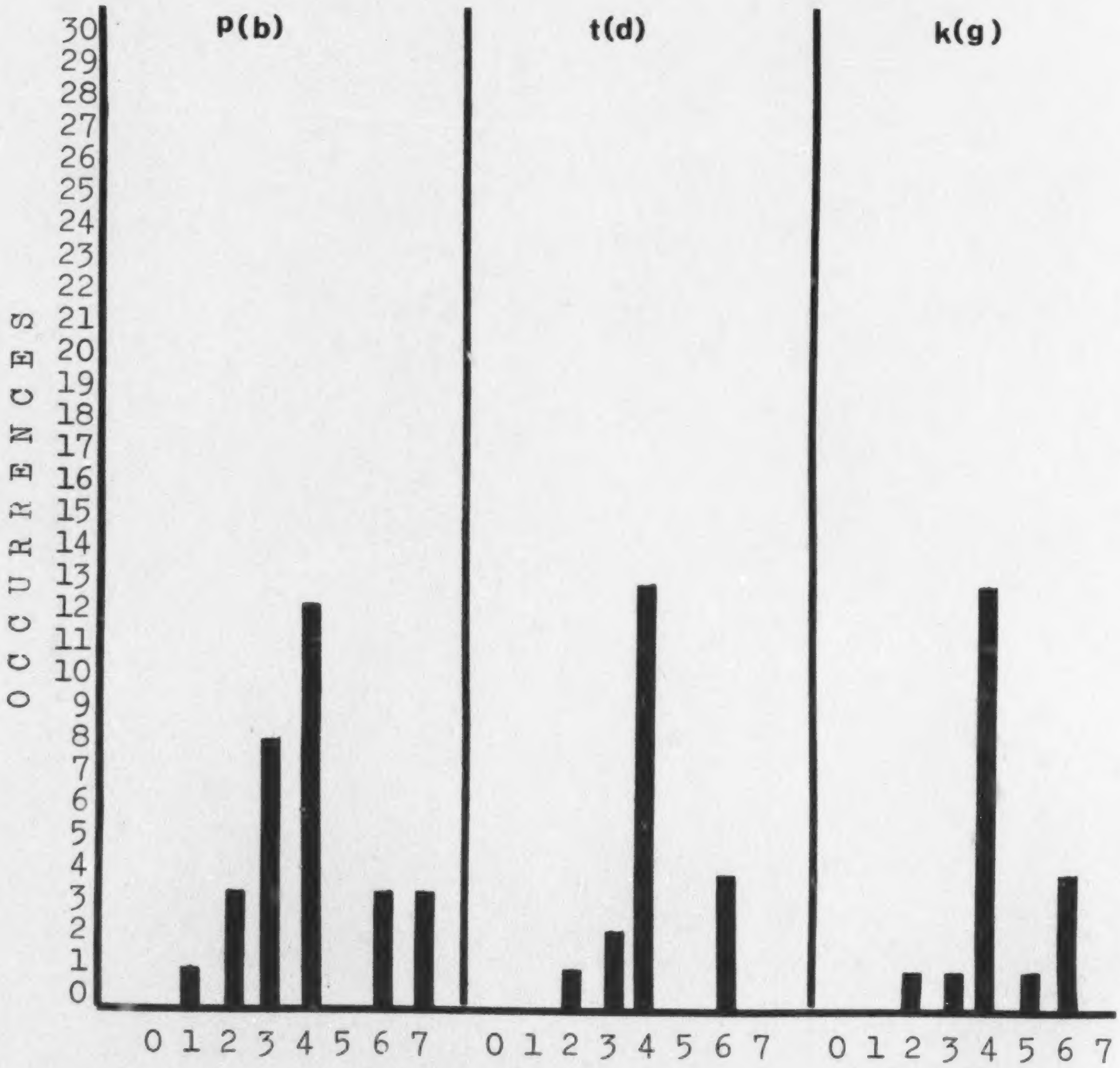
DISTRIBUTION OF RELEASE TYPES FOR GERMAN STOPS

Key:
0 - no release
1 - embryonic vowel
2 - aspiration
3 - burst
4 - burst plus aspiration
5 - burst plus friction
6 - burst plus embryonic vowel
7 - friction



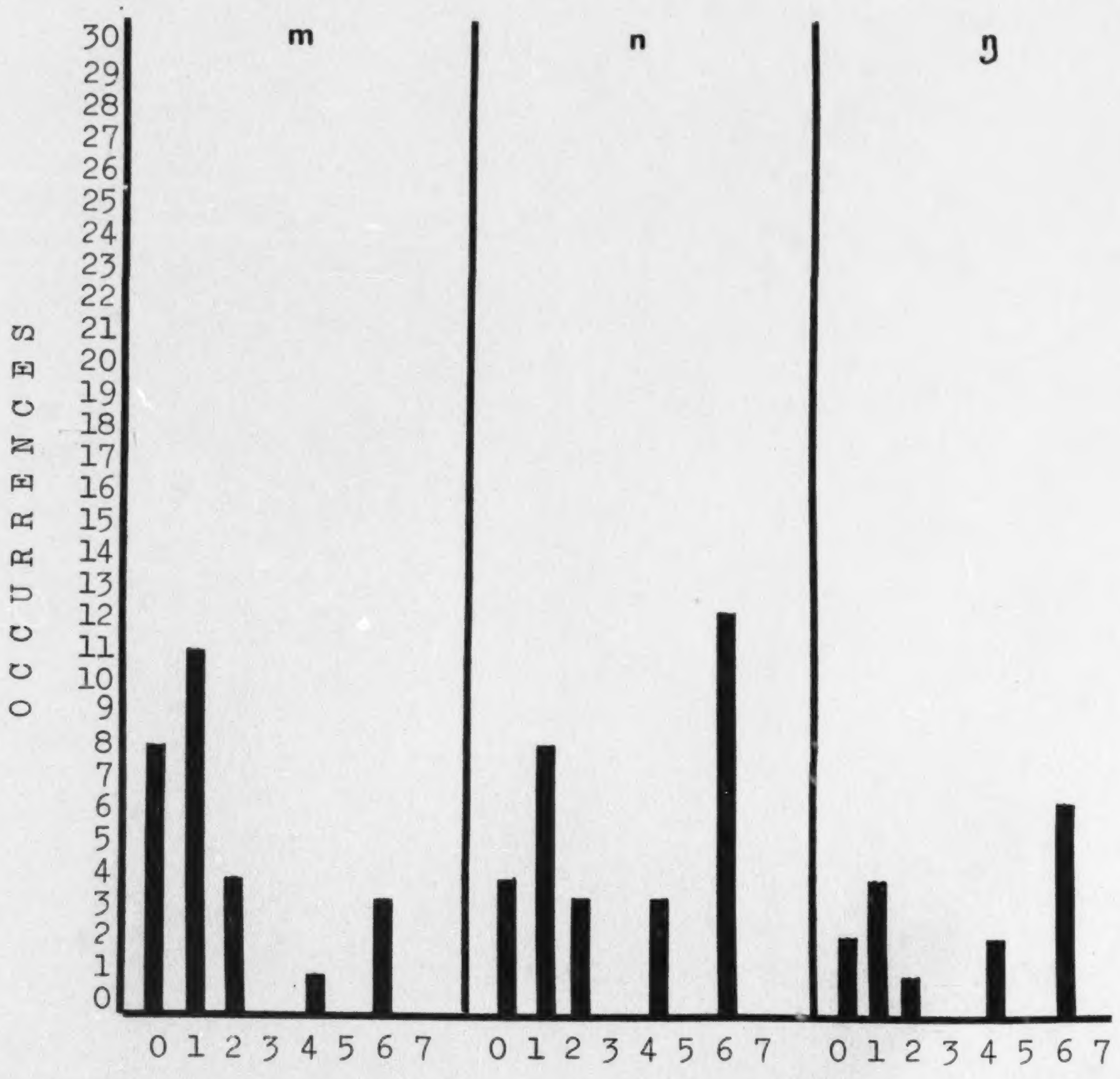
DISTRIBUTION OF RELEASE TYPES FOR GERMAN STOPS

Key:
0 - no release
1 - embryonic vowel
2 - aspiration
3 - burst
4 - burst plus aspiration
5 - burst plus friction
6 - burst plus embryonic vowel
7 - friction



DISTRIBUTION OF RELEASE TYPES FOR GERMAN NASALS

Key:
0 - no release
1 - embryonic vowel
2 - aspiration
3 - burst
4 - burst plus aspiration
5 - burst plus friction
6 - burst plus embryonic vowel
7 - friction



SPANISH DURATIONS

Sentence

	VD	SS	R	CD	TD
k	17.1	6.0	10.5	16.5	33.6
t	17.7	10.4	4.6	15.0	32.7
x	15.2	12.7	.5	13.2	28.3
d	18.4	1.0	-	1.0	19.4
l	14.4	11.5	-	11.5	25.9
r	18.1	7.2	.7	8.0	26.0
n	14.3	11.9	2.1	14.0	28.3
s	20.0	19.4	-	19.4	39.4
θ	17.7	12.3	-	12.3	30.0
ks	14.3	9.8	10.1	19.9	34.2

Word

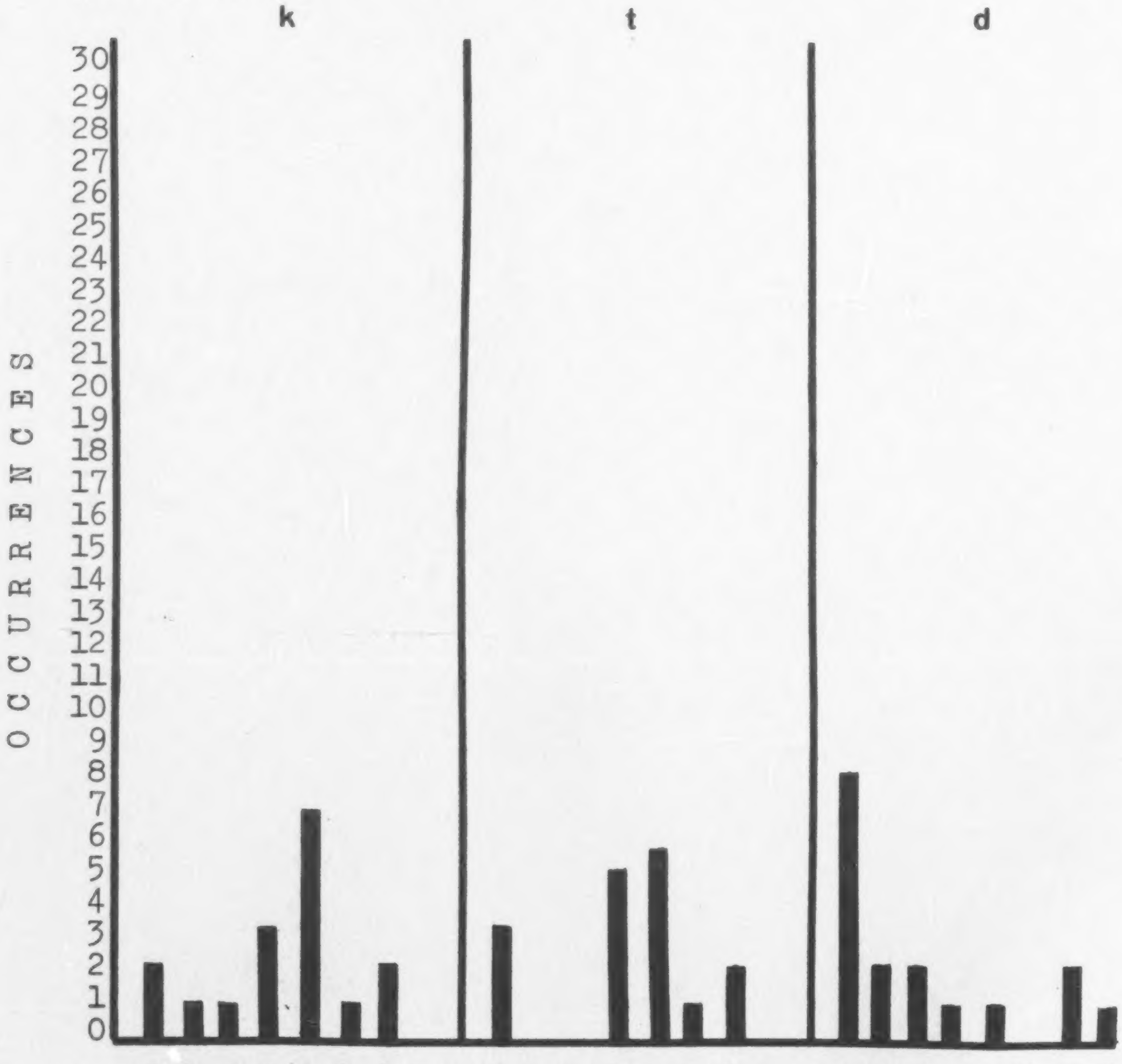
	VD	SS	R	CD.	TD
k	21.1	7.5	12.0	19.6	40.7
t	17.6	7.8	7.7	15.5	33.1
x	15.9	14.8	.5	15.3	31.2
d	21.2	7.4	3.8	11.1	32.4
l	20.4	14.1	3.1	17.2	37.6
r	23.7	8.3	1.2	9.5	33.2
n	20.1	16.8	-	16.8	36.9
s	22.3	20.8	-	20.8	43.1
θ	23.8	8.8	-	8.8	32.6
ks	14.7	10.8	10.9	21.7	36.4

Logatome

	VD	SS	R	CD	TD
k	21.5	9.4	10.3	19.7	41.2
t	20.4	9.5	10.2	19.7	40.0
x	21.8	18.3	-	18.3	40.1
d	29.2	7.1	9.6	16.7	45.9
l	21.2	11.4	4.4	15.9	37.0
r	23.3	8.4	.8	9.2	32.5
n	20.5	13.7	2.3	16.0	36.5
s	20.4	19.1	-	19.1	39.5
θ	19.8	11.0	-	11.0	30.8
ks	17.5	12.9	16.3	29.2	46.6

DISTRIBUTION OF RELEASE TYPES FOR SPANISH STOPS

Key:
0 - no release
1 - embryonic vowel
2 - aspiration
3 - burst
4 - burst plus aspiration
5 - burst plus friction
6 - burst plus embryonic vowel
7 - friction



THE INFLUENCE OF CONSONANTS UPON
CONTIGUOUS VOWELS

PHASE I: VOWEL DURATION

INTRODUCTION

Many factors affect the duration of vowels. Among them are: 1) phonemic duration contrasts, as in French mettre /mɛtr/ vs. maître /mɛːtr/; 2) stress; 3) the identity of the vowel itself; and 4) its phonetic context. Their interaction is very complicated and as yet not completely understood. In this study, we have limited ourselves to one aspect of the vowel's phonetic context, namely the influence of the following consonant. It is noted that phoneticians, working in various languages, have often found such a dependency, and for that reason we feel justified in searching here for a 'language universal'. Our operating hypothesis is quite simple and involves a consonantal parameter that the Principal Investigator has been studying for a number of years under another contract. This hypothesis is as follows: Because of a tendency to anticipate greater efforts more than lesser ones, vowels are shorter before consonants that are felt to involve relatively greater expenditures of articulatory energy, and longer before the more easily produced consonants. Fifteen years of experimentation have indicated that the unvoiced member of each voiced/voiceless (but otherwise identical) pair of consonants is felt to be 'fortis' in comparison to its voiced (hence 'lenis') cognate. Of lesser importance, and in a general way, stops are more fortis than fricatives, and the nasals are the most lenis of all the consonants.

The data used in this study represent a number of different approaches to the problem. For some languages, the measurements have been read from spectrograms; in others they have been made from acoustic oscillograms, using a revolving-head-magnetic-tape scanner (ROMATS); and still others have been taken from intra-buccal air-pressure recordings.

AMERICAN-ENGLISH

The measurements for this phase of the study were extracted from intra-buccal air-pressure recordings, made in connection with the 'force of articulation' studies mentioned above. The vowel duration data, while extremely important to the present study, were a minimally relevant by-product of the earlier studies and would otherwise have been discarded. The recording technique used here has the virtue of yielding the most precise measurements possible of the onset and cutoff points of vowel and consonant articulation. A catheter (Lee DC-12) is inserted via the subject's nostril to the mesopharynx. Its outer end is attached to a fluid-pressure transducer (Statham 131 TC±2.5-350), and writeout is accomplished with a Honeywell medical system and 'Visicorder'. A sample pressure recording is shown in Fig. 1. The curves show departures from ambient air-pressure within the mouth during the occlusion or constriction of consonants. The intra-buccal pressure during the articulation of vowels is not measurably different from outside pressure, as there is no appreciable resistance to air-flow and as flow is reduced practically to zero (hence producing no Bernoulli effect). Thus the duration of vowels that occur between consonants is accurately delineated by the rejoining of the pressure curve of the preceding consonant to the zero (ambient pressure) baseline, and the departure from the baseline of the curve of the following consonant.

Two bodies of data were collected for American-English, as follows: 1) Four logatomes (nonsense words) were recorded as they were uttered ten times apiece by ten speakers of a more or less standard variety of American-English. The test items were two-syllable oxytones, each containing a single consonant in initial, intervocalic, and terminal positions, separated by the vowel /a/, thus providing the vowel in interconsonantal position, once unstressed and once stressed. Table 1 shows the layout and results. 2) A meaningful sentence containing the same consonants as in the logatomes was similarly uttered and recorded ten times apiece by each one of our subjects. The results for this experiment are contained in Table 3. In both series, loudness was held to a constant medium value (appropriate for conversations at four feet), and syllabic rate was controlled at 300/min. by having the subjects speak in rhythm to a metronome.

The measurements obtained from the logatomes strongly support our working hypothesis--see above. With almost perfect consistency, the vowel /a/ before an unvoiced consonant is longer than before its voiced cognate in identical conditions of stress. Only three exceptions appear out of eighty measurements. Although the same general relationships hold in both unstressed and stressed vowels, the values for the latter are much greater, where they are often as much as quadrupled. Also, individual differences merge, which suggests that there are energetic speakers and lax ones.

The results for the meaningful sentence are much less consistent, at least for English. Although 9 of our 10 subjects uttered longer vowels before /z/ than they did before /s/, a majority of them uttered a longer /a/ in Pappa than they did in Bobbie. This is explained by the fact that Pappa occurred in phrase-initial position, its first /a/ hence showing a series effect that we have consistently noted in our air-pressure studies. In this position all measurable parameters of both consonants and vowels regularly have higher values than they do elsewhere.

All of this of course suggests that if vowel durations provide phoneme recognition cues for neighboring phonemes, such as to indicate if the following consonant is a surd or a sonant, the cerebral decoding process must be extremely complicated. It must necessarily account for individual speaker differences, position in the utterance, position with relation to stress, etc. Furthermore, as we shall see from our French and Spanish results, the identity of the vowel itself also influences its duration.

FRENCH

Ten speakers of the dialect characteristic of the Parisian upper middle class recorded the same logatomes as did our American subjects and in the same experimental conditions. They also recorded a meaningful sentence quite similar to the one used in English, ten times each. The same consonants were used and they occurred in similar positions in the sentence and with relation to stress. Only the vowels were different. The measurements were taken from intra-buccal air-pressure recordings made in exactly the same way as in the American-English experiment. The results for the logatomes are shown in Table 2, those for the utterance in Table 3. The opposing cognate measurements for French support our working hypothesis even more strongly than did those for English. Not only are there fewer exceptions, but the contrasts in values are generally greater. The most dramatic difference between the two languages, however, is in the sentence. In the French version, the vowel before each sonant is without exception longer than the vowel before that consonant's voiceless cognate, and in almost all cases, the contrast is dramatic. It is quite possible that the discrepancy between the two languages may be due to the irregular rhythm of English and the unusual syllabic regularity of French.

In order to take vowel differences into account, a second, independent experiment was designed and carried out, using a different group of subjects. These were all Parisian born and educated, and in most cases, at least one of their parents was also Parisian. Four males from 22 to 45 years of age and two females, one a young adult and the other a middle-aged lady, all students or teachers, were used. The test items consisted of one of three vowels (/i, a, u/) in CVC logatomes. The initial consonant was /n/ throughout, while 18 different consonants were used in terminal position. Syllabic rate was held to a constant value of 360/min., and the subjects spoke at a medium level of loudness. Each speaker uttered the 54 items ten times apiece, and these were recorded on magnetic tape. The measurements were extracted with the help of a rotating-head magnetic-tape scanner (ROMATS) --see above. The oscillogram of each item was displayed on a calibrated 19-inch television screen.

Average measurements for each item per speaker and overall averages per item are shown in Table 4. The following observations emerge: 1) All vowels are significantly shorter before a given surd than before its sonant cognate. 2) In similar contexts the vowel /i/ is generally shorter than /u/, and /u/ is shorter than /a/. 3) When voicing and voicelessness are not considered, buccal manner of articulation also affects vowel duration; vowels are longest before liquids, intermediate before fricatives, and shortest before occlusives. Before nasal consonants, they are longer than before surds, but shorter than before liquids or voiced fricatives. It is noted that nasal consonants are voiced occlusives but have a relatively low degree of 'force of articulation'.

GERMAN

Two sets of data were obtained for German: One was extracted from spectrograms made in connection with terminal releases, the other from intra-buccal air-pressure measurements, obtained with a trans-nasal meso-pharyngeal catheter. The numerical results of the first are given in Table 5, those of the second in Table 6.

For the spectrographic phase of this study, five speakers of Standard High German were used. The test items were logatomes (nonsense words), meaningful words, and coherent sentences--see chapter on releases--in which the various consonants occurred post-vocalically in terminal position, both after a short vowel and a long vowel. The letters that are underlined and in parenthesis in Table 5 indicate the graphic representation of the stimuli as given to the subjects. The spectrograms (narrow-band: 45 Hz) were taken from tape recordings made under optimum laboratory conditions. Each item was uttered once by the subjects, speaking at medium values for syllabic rate and loudness.

One aspect of the results constitutes an important discovery: In spite of the devoicing of final surds in German, the contrasting homorganous spelled consonants (/pb/, /kg/, etc.) remain phonetically distinct by virtue of the duration of the preceding vowel, which is relatively short before the surd and long before the sonant. This indicates that the members of such pairs remain conceptually different. The differences are dramatic in all cases but /f/:/v/, where some weak inconsistencies are noted. The averages for each of the two consonants in question are equal.

For the air-pressure-pulse phase of this study, three male and two female subjects were used, ranging in age from 22 to 50 years, all of them of the upper middle-class and speakers of the standard 'High German'. The test items were recorded ten times apiece at two syllabic rates (100/min. and 150/min.) and at two levels of loudness (loud and soft), yielding four measurements which we averaged to obtain the values used in our vowel duration study. Three cognate pairs of voiced/voiceless stops and one pair of fricatives were used. It is noted that a degree of unnaturalness may conceivably characterize the vowels before terminal consonants, as some of our subjects voiced some of these consonants. However, if this had had a demonstrably adverse effect, we would expect the vowel duration values before terminal surds and sonants to be non-contrastive, and an examination of our results--see Table 6--will show that this was certainly not the case.

The results are in very close agreement with those of American-English and French. For all of our speakers, the average values for the voiceless consonants are greater than for their voiced cognates, except for one subject's unaccented /a/s in /tatát/ and /dadád/. The overall averages show no exceptions. As for the magnitudes of the values, the contrasts between the opposing members of cognate pairs was small, often minimal, among unstressed vowels. Among stressed vowels, however, the contrasts were often dramatic. Our operating hypothesis is thus further supported by the data for German.

SPANISH

Our Spanish vowel duration measurements were obtained entirely from spectrograms of meaningful words, as uttered by three Spaniards and two Argentinians, all of them educated men from metropolitan areas. The items were recorded at an average syllabic rate and at a normal conversational level of loudness. Spanish presents special difficulties, with respect to the present study: First, that language does not have the voiced/voiceless cognate contrasts in terminal position that characterize other Indo-European languages, since voiced occlusives in that position become fricatives and tend to lose their voicing. Also, these fricatives in terminal position are often so weak as to be impossible to measure, which explains the blanks in the data. The numerical results for Spanish are given in Table 7.

Notwithstanding these difficulties, some interesting observations emerge from the data: In a general way, they support the results from the other languages. Vowels before voiceless consonants are, on the average, shorter than before voiced consonants. They also tend to be shorter before stops than before fricatives. However, probably because of the characteristically lax articulation of that language, as compared to the others, there is much less consistency in the repetitions of each item than in English, French, or German. Finally, vowel duration again appears to be affected by the identity of the vowel itself. In articulatory terms, the smaller the aperture of the vowel, the shorter it tends to be, all other factors being equal. In acoustic terms, the higher the frequency of F1 and the lower the frequency of F2, the longer the vowel. An interesting comparison between French and Spanish, in this respect, is seen in Fig. 2.

CONCLUSION

The results of the various phases of this study strongly suggest that a 'language universal' exists in the sensitivity of the duration of vowels to their phonetic context and in their own intrinsic relative durations. As we have seen, however, the magnitudes can vary greatly from one speaker to another, and absolute values can therefore not be posited. Furthermore, one feature of our experimental design makes it impossible to compare the results of the four languages in question: Since each language involved a different group of speakers (two for French), individual differences cannot be separated from language differences with any degree of certainty. In order to resolve this question, groups of bi-lingual subjects or polyglots would be needed, but again, no accurate measure of fluency in the various languages is currently available.

Table 1

AMERICAN VOWEL DURATION AS A FUNCTION OF FOLLOWING CONSONANT

(durations in msecs)

S	Unstressed /a/				Stressed /a/			
No.	/papáp/	/babáb/	/sasás/	/zazáz/	/papáp/	/babáb/	/sasás/	/zazáz/
1	50	64	41	57	245	331	280	377
2	93	78	27	82	276	387	326	392
3	72	79	50	62	215	288	266	339
4	90	97	79	72	245	249	303	440
5	44	47	13	93	229	346	333	391
6	81	92	63	81	246	375	316	371
7	47	65	57	99	209	306	368	363
8	54	62	11	34	269	417	348	430
9	88	129	23	85	204	274	268	353
10	101	146	87	79	279	379	367	416
Avgs.	72.0	85.9	45.1	74.4	241.7	335.2	312.5	387.3

Table 2

FRENCH VOWEL DURATION AS A FUNCTION OF FOLLOWING CONSONANT

(durations in msecs)

S	Unstressed /a/				Stressed /a/			
No.	/papáp/	/babáb/	/sasás/	/zazáz/	/papáp/	/babáb/	/sasás/	/zazáz/
1	104	130	95	94	137	258	156	201
2	114	140	120	133	179	245	197	263
3	113	184	129	179	142	199	184	226
4	159	205	118	151	145	210	183	221
5	129	205	153	150	151	254	270	258
6	63	91	63	66	149	251	220	268
7	84	109	90	130	171	257	177	291
8	65	77	83	73	95	131	123	157
9	95	129	100	144	204	249	214	323
10	72	86	67	72	205	324	237	264
Avgs.	99.8	135.6	101.8	119.2	157.8	237.8	196.1	247.2

Table 3

AMERICAN AND FRENCH VOWEL DURATION IN NORMAL UTTERANCES

(durations in msecs)

	American				French			
S No.	Pappa and	Bobby	sang a song about	the Zuider Zee	Pépé maintenant	Bébé sans	souci, c'est	Zazie
1	170	133	30	54	119	122	99	114
2	165	189	62	65	65	102	26	109
3	152	154	52	58	73	94	9	140
4	181	151	74	39	83	63	38	93
5	166	168	29	50	89	123	68	132
6	166	125	76	80	85	156	38	160
7	212	129	38	41	94	123	88	133
8	177	168	60	71	88	131	68	176
9	180	148	39	91	50	75	38	95
10	169	127	60	75	59	90	11	100
Avgs.	173.8	149.2	520	62.4	80.5	107.9	48.3	119.2

Table 4

FRENCH VOWEL DURATION MEASUREMENTS FROM OSCILLOGRAMS

Items	Subjects (avgs.) 1	2	3	4	5	6	Overall Avgs.
nip	6.9	10.0	9.5	7.3	9.0	9.9	8.8
nib	9.8	12.9	11.3	10.6	12.2	10.6	11.2
nit	7.1	11.7	19.2	8.2	10.6	9.5	11.1
nid	11.1	15.5	11.7	13.5	17.8	11.3	13.5
nik	5.8	11.1	9.5	7.7	9.6	8.0	86.1
nig	8.0	13.4	10.8	10.3	13.5	9.1	10.9
nim	10.3	13.2	12.4	8.3	12.2	11.8	11.4
nin	11.0	- - -	12.9	- - -	15.5	11.7	12.7
niɲ	10.2	16.6	12.4	8.0	15.3	9.1	11.9
nif	11.4	12.6	11.6	5.8	10.6	9.9	8.7
niv	13.8	13.9	13.2	14.6	14.8	11.8	13.7
nis	11.1	13.7	9.8	9.8	15.9	10.5	11.8
niz	13.9	18.2	13.8	14.3	25.5	13.0	14.8
niʃ	11.4	13.9	13.1	10.8	15.1	11.0	12.6
niʒ	17.1	21.0	22.1	17.7	26.4	14.6	19.8
nir	19.4	18.3	14.3	13.4	26.1	13.7	17.5
nil	15.9	18.4	15.3	14.1	21.1	13.1	16.3
nij	20.1	25.5	10.3	16.9	26.2	11.4	18.4
nap	8.5	10.5	10.8	10.2	8.3	10.8	9.9
nab	11.8	14.5	13.6	13.4	11.8	12.9	13.0
nat	10.7	11.3	11.1	12.5	7.4	11.5	11.1
nad	14.7	16.0	13.3	13.5	12.1	13.7	13.9
nak	9.5	12.3	10.1	10.0	10.0	12.0	10.7
nag	13.1	16.1	11.1	12.9	11.2	14.4	13.1
nam	13.1	13.7	14.1	11.8	13.0	13.0	13.1
nan	14.0	- - -	16.3	- - -	11.7	13.0	13.7
naɲ	14.6	15.4	15.3	11.9	12.6	12.6	13.7
naf	11.6	12.4	10.4	9.3	11.0	11.5	11.0

Table 4 Cont'd.

Items	1	2	3	4	5	6	
nav	15.6	16.0	14.4	15.2	16.8	13.5	15.3
nas	12.1	14.4	11.5	12.2	13.3	12.3	12.6
haz	19.7	18.8	14.7	15.3	19.2	14.3	17.0
naʃ	12.6	15.0	18.8	15.7	14.0	11.8	14.7
naʒ	21.9	22.8	15.7	18.2	19.5	14.6	18.8
nar	22.5	22.9	17.0	13.9	21.1	15.0	18.7
nal	18.2	19.5	15.0	14.5	19.5	14.3	16.8
naj	23.0	20.8	13.7	17.5	19.6	13.8	18.1
nup	6.7	11.4	10.1	11.1	9.0	9.1	9.6
nub	8.5	14.3	13.1	15.4	12.2	11.6	12.5
nut	8.6	13.7	11.1	12.2	10.6	11.3	11.3
nud	12.0	16.8	16.1	17.9	17.8	12.2	15.5
nuk	7.2	12.0	9.6	9.4	9.6	9.5	9.6
nug	8.2	16.3	11.5	13.1	13.5	12.9	12.6
num	11.8	13.0	14.5	12.0	12.2	12.0	12.6
nun	10.5	- - -	14.4	- - -	15.5	13.6	13.5
nuɲ	11.6	18.1	14.1	9.8	15.3	12.7	13.6
nuf	9.1	11.9	10.5	9.0	10.6	10.2	10.2
nuv	11.5	15.4	13.2	17.7	14.8	12.5	14.8
nus	10.5	15.5	10.7	13.5	15.9	11.0	12.9
nuz	16.1	22.0	14.5	17.7	25.5	13.2	16.5
nuʃ	13.2	16.0	16.5	16.2	15.1	10.9	14.7
nuʒ	21.1	21.8	13.8	19.3	26.4	13.5	19.3
nur	18.8	22.1	18.2	14.7	26.1	14.9	19.1
nul	16.9	19.4	11.3	14.8	21.1	13.9	16.2
nuj	19.6	18.5	12.2	20.4	26.2	12.7	18.3

Table 5

GERMAN VOWEL DURATIONS FROM SPECTROGRAMS

Vowel	Sentence	Word	Logatome	Average
long p	17	19	24	20
short	12	12	9	11
long p(b)	24	26	26	25
short	14	12	12	13
long t	28	26	24	26
short	11	11	11	11
long t(d)	27	27	29	28
short			14	(14)
long k	22	24	25	24
short	10	12	10	11
long k(g)	24	25	27	25
short			13	(13)
short pf	10	11	11	11
long ts	25	25	29	26
short	13	13	13	13
long m	28	29	29	29
short	9	10	13	11
long n	27	33	27	29
short	12	13	13	13
short ŋ	13	12	14	13
long f	29	30	29	29
short f(v)	13	15	12	13
long	28	28	31	29
short			19	(19)
long s	27	29	33	30
short	12	13	14	13
short ʃ	15	14	13	14
long ʒ	33	34	30	32
long x	21	23	27	24

Table 5 Cont'd.

short		14	13	12	13
long	r	30	31	30	30
short		20	20	17	19
long	l	28	29	27	28
short		13	13	14	13

Table 6

GERMAN VOWEL DURATION AS A FUNCTION OF FOLLOWING CONSONANT

(durations in msec)

S No.	unstressed /a/ /papáp/	/babáb/	/tatát/	/dadád/	/kakák/	/gagág/	/faváv/	/vaváv/	stressed /a/ /papáp/	/babáb/	/tatát/	/dadád/	/kakák/	/gagág/	/fafáf/	/vəváv/
1	92	101	94	122	85	112	79	111	123	170	151	231	116	177	119	204
2	85	104	105	104	88	102	78	102	105	163	121	170	121	153	95	144
3	100	120	122	130	110	112	116	116	144	200	186	247	147	239	141	291
4	66	73	63	83	60	74	60	88	86	119	92	136	89	135	100	152
5	60	80	77	99	74	108	77	80	100	128	102	141	99	127	95	110
Avgs.	80.6	95.6	92.2	107.6	83.4	101.6	79.6	99.4	111.6	156.0	130.4	185.0	114.4	166.2	110.0	180.2

Table 7

SPANISH VOWEL DURATION MEASUREMENTS

(Durations in msecs)

	Subjects					
Items	1	2	3	4	5	Avgs.
frac	18	20	11	27	21	19.4
de frac	18	15	18	16	19	17.2
mac	26	22	19	25	19	22.2
fíat	16	16	18	21	21	18.4
el fíat	17	15	12	18	15	15.4
déficit	9	17	12	16	16	14.0 (17.5)
en déficit	8	11	17	9	20	13.0
complot	8	17	15	21	19	16.0
el complot	15	18	25	15	22	19.0
mat	20	21	21	20	18	20.0
reloj	--	15	22	24	14	18.7
el reloj	--	16	22	12	13	15.7
carcaj	--	--	--	30	--	30.0 (21.5)
el carcaj	--	--	--	17	--	17.0
maj	--	15	33	25	19	26.0
mad	--	27	--	31	28	28.6
césped	--	15	--	15	5	11.6
el césped	--	9	--	12	8	9.6
cuidad	--	21	--	29	20	23.3 (18.0)
la cuidad	--	13	--	18	20	17.0
esperad	--	22	--	29	15	22.0
grite esperad	-	19	--	19	20	19.3

Fig. 1
AIR-PRESSURE RECORDING

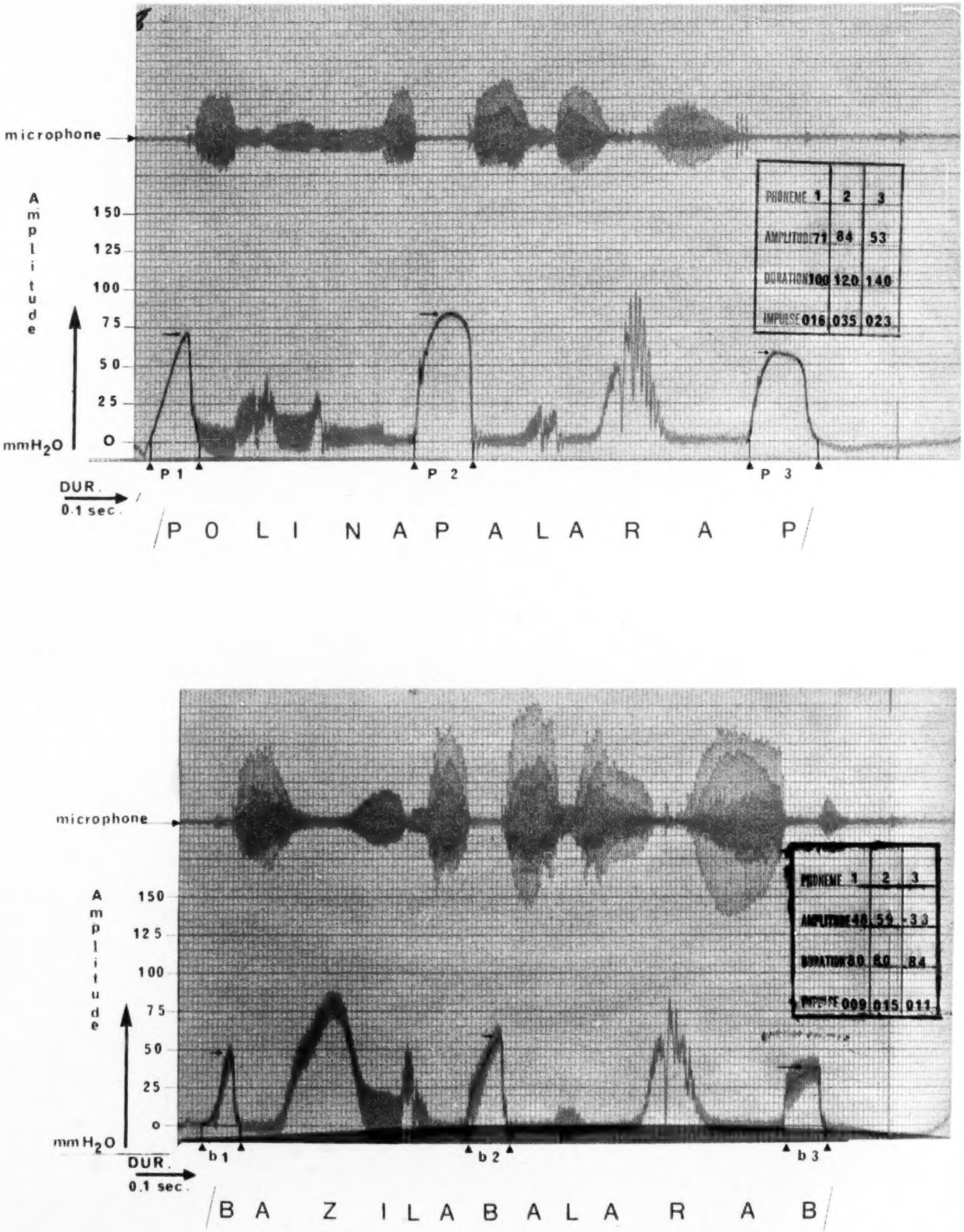
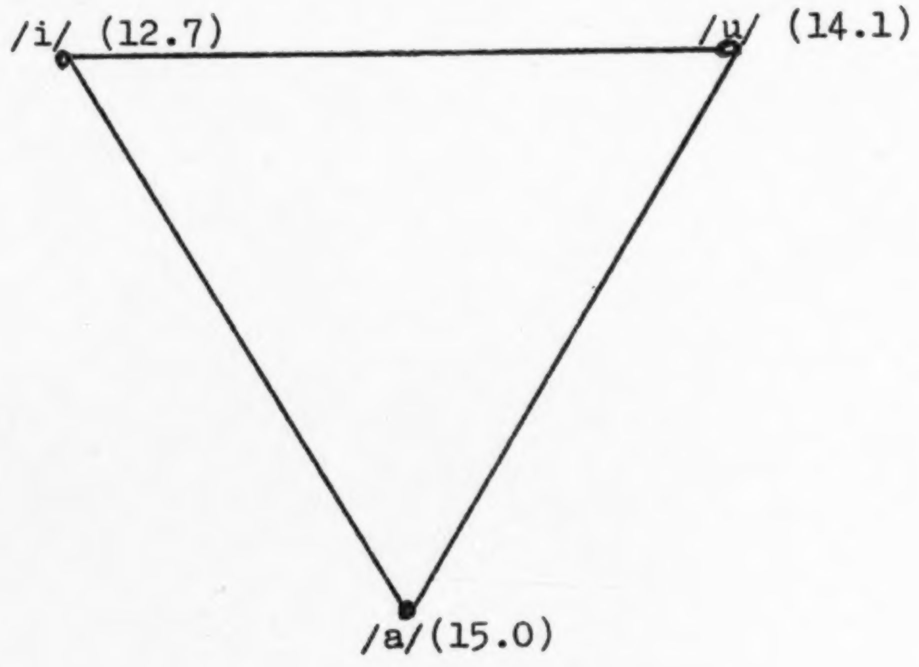


Fig. 2

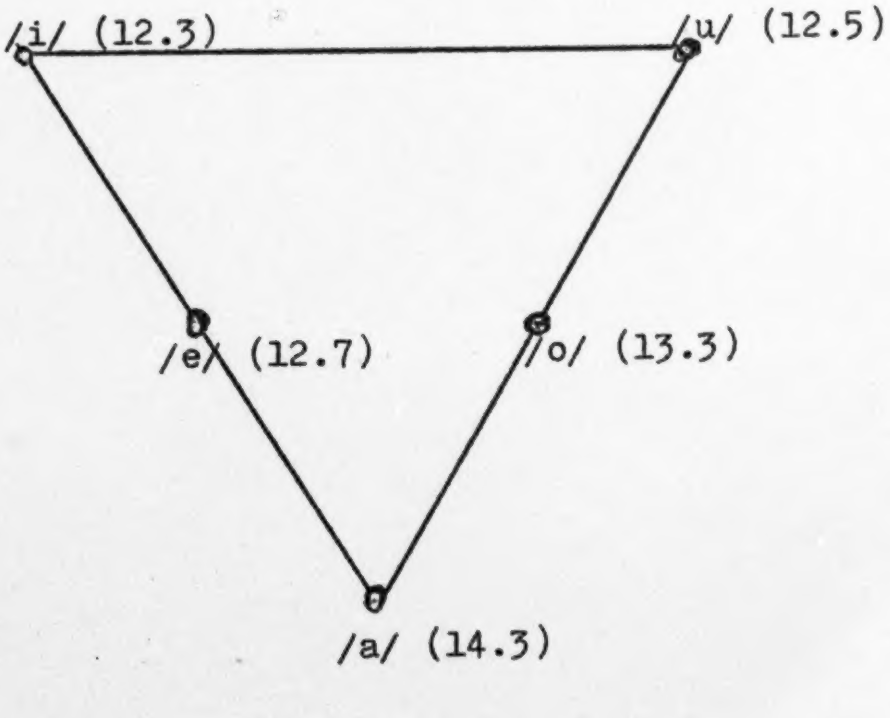
INTRINSIC VOWEL DURATION IN FRENCH AND SPANISH

(Average values in msecs)

French:


/i/ (12.7)
/u/ (14.1)
/a/(15.0)

Spanish:


/i/ (12.3)
/u/ (12.5)
/e/ (12.7)
/o/ (13.3)
/a/ (14.3)

VOWEL-COLOR OF GERMAN /E/ SOUNDS

INTRODUCTION

The number of German /E/ sounds is, both in practice and in theory, subject to dispute. The vowel system of Standard High German contains six short open vowels and six long closed vowels--without the /E/sounds that seemingly destroy the symmetry. Opinions of phoneticians, past and present, vary in regard to number and type of the /E/ sounds. There is consensus about the existence of four E sounds /e:, e, ε:, ε/during the Middle High German period and about the current existence of two phonemes /e:, ε:/--of which the latter is an anomaly in as far as it is the only German vowel that is open and long.[1] Moulton expresses the problem in the introductory lines to his chapter "The Vowels of German" as follows: "In stressed position, German has seventeen contrasting vowels and diphthongs, plus an eighteenth vowel which is prescribed by the Siebs but is of marginal status for a good many speakers". Thus, he includes three /E/ sounds in his phonemic transcriptions of German vowels and offers the following minimal pairs for their characterization:[1]

/e/	beten	stehle
/ę/	Betten	Stelle
/ε/	bäte	stähle

For our study, we will use a different transcription:

Moulton	/ẹ/	Ours	/e:/
	/ę/		/ε/
	/ε/		/ε:/

Von Essen[2] concurs in that opinion, and so does essentially Wängler.[3] Delattre[4] by contrast admits to only two German /E/ phonemes, which he transcribes as /e/ and /ε/ and defines as "long and closed" and "short and open". Siebs,[5] already quoted by Moulton, is uncertain. He recognizes three /E/ sounds, (in our transcription /e:/, /ε:/, /ε/) but gives to the third phoneme a variable vowel color, [e] vs. [ε] which he tries to explain by the consonantal environment and duration.

We can see that the dispute centers around the present existence of either one or two short phonemes /e/ or /ε/. The issue is complicated by two factors:

1) The grammarians of the 16th and 18th centuries adopted a standard orthography which for the /E/ sounds was based on word association and not on sound (ex: Hände but behende) and hence created a "Schriftsprache" which in turn influenced the pronunciation of the literate public.

2) The dialectal influences of the great linguistic belts are diametrically opposed to one another: the southern ones favor /ɛ/ over /e/ and the northern ones o /e/ over /ɛ/.

The purpose of this study is to investigate the number and type of the German /E/ sounds via acoustic analysis and synthesis. Particular emphasis will be given to the short vowels.

PART I

(Spectrographic Analysis)

1. Procedure:

a) A corpus of minimal pairs was compiled, containing all theoretically possible /E/-oppositions:

--/eː/-/ɛː/	beten	bäten
	zehren	Zähren
	Fehden	Fäden
--/eː/-/e-ɛ/	beten	Betten
	zehren	zerren
	Fehden	fetten
--/ɛː/-/e-ɛ/	ässe	esse
	mässe	messe
	vergässe	vergesse
	träfe	treffe
	käme	Kämme
	schäle	Schelle
	Hähne	Henne
	Kähne	kenne
	dräsche	dresche

	erschräke	erschrecke
	frässe	fresse
	räte	rette
	stäche	steche
	Käte	Kette
--/e/-/ε/	werter	Wärter
	Stelle	Ställe

b) To counteract the "Schriftsprache" influence, the words of the corpus appeared on the recording list not only in random order but both singly and in sentences:

Ässe er die Suppe, wäre er nicht mehr hungrig.
Er esse den Apfel.
Ich mässe gern die Fenster.
Ich messe die Rahmen.
Er behauptet, er vergässe stets die Nummer.
Ich vergesse es nie.
Sie träfe mich lieber um fünf Uhr.
Er treffe mich um eins.
Wenn er nur käme.
Die Kämme sind sauber.
Maria schäle zuerst die Kartoffeln.
Diese Schelle ist zu laut.
Die Hähne krähen.
Die Henne gackert.
Die Kähne liegen am Ufer.
Ich kenne das.
Wenn er nur den Weizen dräsche.
Ich dresche den Hafer.
Ich erschrecke nicht leicht.
Wenn sie nur nicht so erschräke.
Wenn der Hund das frässe.
Die Kuh fresse dieses Heu.
Ich räte dir gern.
Rette dich.

Die Biene stäche dich sofort.
Ich steche mich nie.
Käte kommt heute.
Diese Kette ist echt.
Die Frauen beten.
Die Betten wurden gelüftet.
Man sagt, sie bäten nie um etwas.
Sie zehren von der Hoffnung eines Wiedersehens.
Die Kinder zerren den Hund.
Zähren zeichneten die Wangen.
Die Fehden waren endlos.
Die Bauern fetten die Schweine.
Fäden hängen vom Rock.
Mein werter Herr von Oldenburg!
Der Wärter schloss den Käfig.
Wie gefällt Ihnen die Stelle?
Unsere Ställe sind halbleer.
Das Kind hält den Hund an der Leine.
Der Held kehrte von dem Kampf zurück.

c) Only phonetically naive German natives, speaking the standard language, were asked to record. Six male informants were used and each recorded the entire corpus twice.

d) As a countercheck in regard to dialectal influences, natives from Bremen and Munich were recorded on location.

e) About a thousand spectrograms were made of the recorded material, some presenting more than one occurrence of the /E/ sounds.

f) The spectrograms in turn were analyzed, and the durations and formant-frequencies of the vowels in question were measured and recorded.

We know that the main physical correlates of vowel distinction are color and duration. Acoustically, vowel color is mainly characterized by the frequencies of the first two formants. Both frequency (via possible anticipation) and duration are influenced by following consonants. The words of the corpus contained therefore the widest possible range of consonant phonemes, thus conferring a certain degree of accuracy to the averages derived from the individual measurements.

Results:

The following results represent the averages of all recorded utterances by all the informants.

a) Duration: The duration for the long phonemes /e:/ and /ɛ:/ averaged 20 centiseconds and for the short phonemes /e/ or /ɛ/ 10 centiseconds. The duration measurements correspond to Viëtor's[6] duration ratio of 2 to 1 for long versus short vowels.

Duration can therefore be ruled out as a possible cue in this investigation since it offers no additional distinctive feature beyond the undisputed long-short opposition.

b) Formant Frequencies:

Opposition /e:/-/ɛ:/

	/e:/	/ɛ:/	Difference
F2	2283 cps	2032 cps	251 cps
F1	417 cps	540 cps	123 cps

Opposition /e:/-/e-ɛ/

	/e:/	/e-ɛ/	Difference
F2	2283 cps	2026 cps	267 cps
F1	417 cps	533 cps	116 cps

Opposition /ɛ:/-/e-ɛ/

	/ɛ:/	/e-ɛ/	Difference
F2	2032 cps	2039 cps	7 cps
F1	540 cps	565 cps	15 cps

Opposition /e/-/ɛ/

	/e/	/ɛ/	Difference
F2	2141 cps	1855 cps	286 cps
F1	497 cps	543 cps	50 cps

As stated above, duration has been ruled out as a distinctive feature, leaving vowel-color as the essential cue.

Vowel-color, in turn, is expressed by formant-frequencies. The average measurements of the preceding chart reveal that:

a) The /eː/-/ɛː/ opposition is characterized by vowel-color.

b) The /ɛː/-/e-ɛ/ opposition is characterized by duration.

c) The /eː/-/e-ɛ/ opposition does not exist. In each instance /e/ has been replaced by /ɛ/.

d) The /e/-/ɛ/ opposition is realized and characterized by a strong vowel-color difference.

Evaluation:

a) German still has four /E/ sounds that are phonemic: /eː/, /ɛː/, /e/, /ɛ/. Their realization, however, seems to have been limited to one perceptual cue for each opposition, in contradiction to the six other German vowel pairs.

b) It is a known fact, that formant frequencies represent no absolute values: each vowel has a limited range for F1 and F2. (The range for /e/ is F1 350-500, F2 2200-2400; the range for /ɛ/ is: F1 500-650, F2 1800-2000). This investigation, however, seems to indicate, that more important than F1 and F2 frequency ranges are the intervals between F1 and F2. The interval for /e/ is 1860 cps and for /ɛ/ 1492 cps.

c) The target of this study was to ascertain the existence or non-existence of two short vowel-phonemes in contemporary German. The spectrographic analysis shows, that the distinction between /e/ and /ɛ/ is still made, but only in isolated words, where vowel-color is the only perceptual cue. Nevertheless, a small reduction seems to have occurred because the F1 and F2 intervals are slightly smaller than for their long counterparts:

/e/ 1644 cps

/ɛ/ 1310 cps

The interval reduction is caused by the quasi-elimination of the frequency difference between the first formants. (There is no evidence, that duration affects first formant frequencies).

PART II

(Perception Tests)

Hypothesis:

The results of the spectrographic analysis indicate that the /e/-/ɛ/ opposition is based on vowel-color and furthermore, that the vowel-color distinction is acoustically characterized mainly by the different frequencies of F2. Therefore, a synthetic pattern, representing a minimal pair (werter/Wärter [vertər/vɛrtər]), with a stable F1 frequency value of about 500 cps, an F2 frequency of upward of 2100 cps for /e/ and an F2 frequency below 2000 cps for /ɛ/ should lead to positive identification of [vertər] versus [vɛrtər] by naive listeners.

Procedure:

a) Two synthesizers were available: one Voback (18 channels, variable intervals), one Cooper-Playback (50 channels, intervals of 120 cps). Two synthetic patterns (one for each machine, to balance possible electronic limitations) were designed.

b) Each of the two patterns represented the minimal pair [vertər/vɛrtər] and had only one variable: the 2nd formant. Four stimuli were created for each pattern: two corresponding to the optimum values obtained from the spectrographic analysis and two intermediate variables.

c) Recordings were made from each of the pattern sequences. The tapes were spliced and reassembled in sequences that represented two types of perception tests: 1. pair comparison, 2. identification of single stimuli.

d) The two separate tests from each of the two synthesizer patterns were given to two groups of naive informants: to ten native Germans and to ten Americans.

e) The results were statistically computed.

Results:

a) Voback

Frequencies of the patterns

F1	450			
F2	Stimulus	1	1920	/e/
	"	2	1770	/e/
	"	3	1490	/ε/
	"	4	1250	/ε/

The F2 frequencies are expressed in frequency-intervals and it should be remembered, that the spectrographic analysis furnished frequency intervals for /e/ of 1644 and for /ε/ of 1320.

Identification

Positive identification of either [vertər] or [vεrtər] expressed in percentiles representing the averages of both the pair-comparison and single stimulus tests:

Stimulus		Native Germans		Native Americans
1	1920	89.2	as /e/	93.9
2	1770	92.6	as /e/	89.4
3	1490	56.6	as /ε/	72.2
4	1250	93.0	as /ε/	90.1

Remarks

The German natives perceived pattern 2 as optimum for [vertər] namely the frequency interval closest to the interval furnished by the spectrographic analysis. (Americans gave a slight preference to the higher frequency interval).

Both Germans and Americans agreed in the perception of pattern 4 as the optimum for [vεrtər] which is again the interval closest to the analysis-average of 1312 cps.

b) Cooper-Playback

Frequencies of the patterns

The Cooper-Playback patterns had an invariable F1 at 480 cps and slightly different F2 frequency intervals than the Voback patterns (1800, 1560, 1320 and 1080 cps, respectively).

Identification

Positive identification of either [vertər] or [vɛrtər] expressed in percentiles representing the averages of both the pair-comparison and single stimulus-identification tests:

Stimulus		Native Germans		Native Americans
1	1800	93.2	as /e/	90.6
2	1560	84.5	as /e/	78.0
3	1320	89.3	as /ɛ/	82.4
4	1080	90.8	as /ɛ/	93.3

Results: [vertər] [vɛrtər] (werter/Wärter) Tests

10 Native Germans and 10 Americans(percentages underlined)

(1-18)	Voback	(19-30)	(1-18)	Cooper	(19-30)
	1			1	
90.9		97.0	93.3		90.0
88.5		90.0	96.7		90.0
	2			2	
90.9		87.9	86.0		70.0
88.5		96.7	85.7		83.3
	3			3	
78.8		69.7	88.0		76.7
63.2		50.0	88.6		90.0
	4			4	
87.3		93.9	93.3		93.3
87.7		100.0	88.3		93.3

Remarks

Both Germans and Americans agreed in the optimum identification of stimulus 1 as the optimum for [vertər]. Again, stimulus 1 had an interval value closest to its statistical equivalent.

Both Germans and Americans preferred stimulus 4 for [vɛrtər] which had actually a lower frequency interval than the statistical average of the spectrographic analysis. However, Germans preferred stimulus 4 by a very slight higher percentage whereas Americans indicated their preference by a wider margin. This seems logical, since the frequency interval of stimulus 4 corresponds more closely to the interval given for the American /æ/.[7] The Germans, however, favored a more pronounced distinction.

Conclusion:

In this spectrographic and synthetic acoustic analysis of German vowel oppositions, we encounter the rather unusual feature that the phonemic distinction is made not on the basis of a bundle of acoustic cues, but instead, on the basis of only one cue, namely either duration or vowel-color. In the case of the disputed /e/-/ɛ/ opposition, the results of the spectrographic analysis are corroborated by those of psycho-acoustic tests conducted with two speech synthesizers. When the duration becomes neutralized as it occurs in natural speech with these two vowels, the phonemic distinction is carried by the difference in formant frequencies (vowel-color).

Footnotes

1. William G. Moulton, *The Sounds of English and German*, the University of Chicago Press, Chicago and London, 1962, pp. 61, 62.

2. Otto von Essen, *Allgemeine und Angewandte Phonetik*, Akademie Verlag, Berlin, 1962, p. 75.

3. Hans Heinrich Wängler, *Atlas deutscher Sprachlaute*, Akademie Verlag, Berlin, 1962, pp. 35, 38.

4. Pierre Delattre, *Comparing the Phonetic Features of English, German, Spanish and French*, Julius Groos Verlag, Heidelberg, 1965, p. 59.

5. Siebs, *Deutsche Hochsprache*, Herausgegeben von Helmut de Boor und Paul Diels, Walter De Gruyter and Co., Berlin, 1961, p. 42.

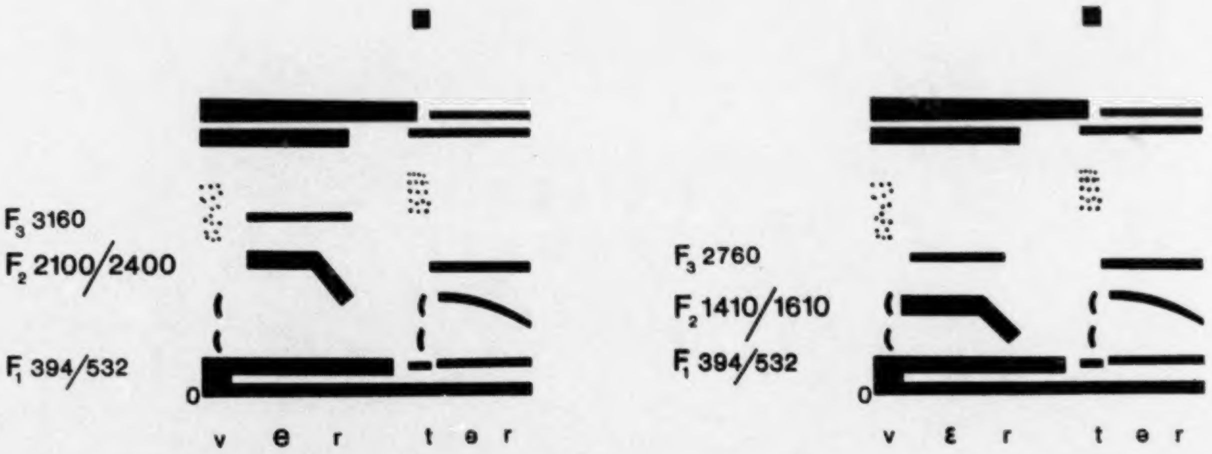
   "III. Kurzes offenes e (ɛ). Dieses e (ɛ) ist zu sprechen, wo e oder ä vor mehreren Konsonanten oder sch steht: Held, hält, schlecht, Nächte, Eltern, älter, Bett, Scherz, Wäsche, Esche. Wo die Konsonantenhäufung erst spät durch Ausfall eines Vokals oder durch Antreten einer Ableitungssilbe entstanden ist, bleibt die Länge gewahrt: gebt aus gebet, erklärt aud erkläret; ebenso in Gemälde, gramlich, Märchen, Rätsel usw. .... Wechselnde Quantität herrscht vor ss (lang in : sässe, Spässe, aber kurz in: hässlich, grässlich), und vor ch (lang in: spräche, bräche, stäche, aber kurz in: sprechen, brechen, stechen) und vor r plus Dental (lang in: Erde, Herde, Herd, Pferd, erst, Fährte, aber kurz in: Gerte, fertig, Härte, widerwärtig)".

6. Wilhelm Viëtor, *Elemente der Phonetik des Deutschen, Englischen und Französischen*, O.R. Reisland, Leipzig, 1923, p. 323:

   "......... Auch für meine Aussprache erhalte ich 0, 3 Sek. als Durchschnittsdauer langer Vokale wie in Pape, Gutenberg, während kurzen Vokalen in gleicher Stellung, z.B. Pappe, Guttenberg, nur 0,15 Sek. als Durchschnitt zukommen. Das Verhältnis ist also nicht 5 : 3, auch nicht 3 : 2, sonder 2 : 1. ....."

7. Ibid., Delattre, p.49.

VOBACK PATTERNS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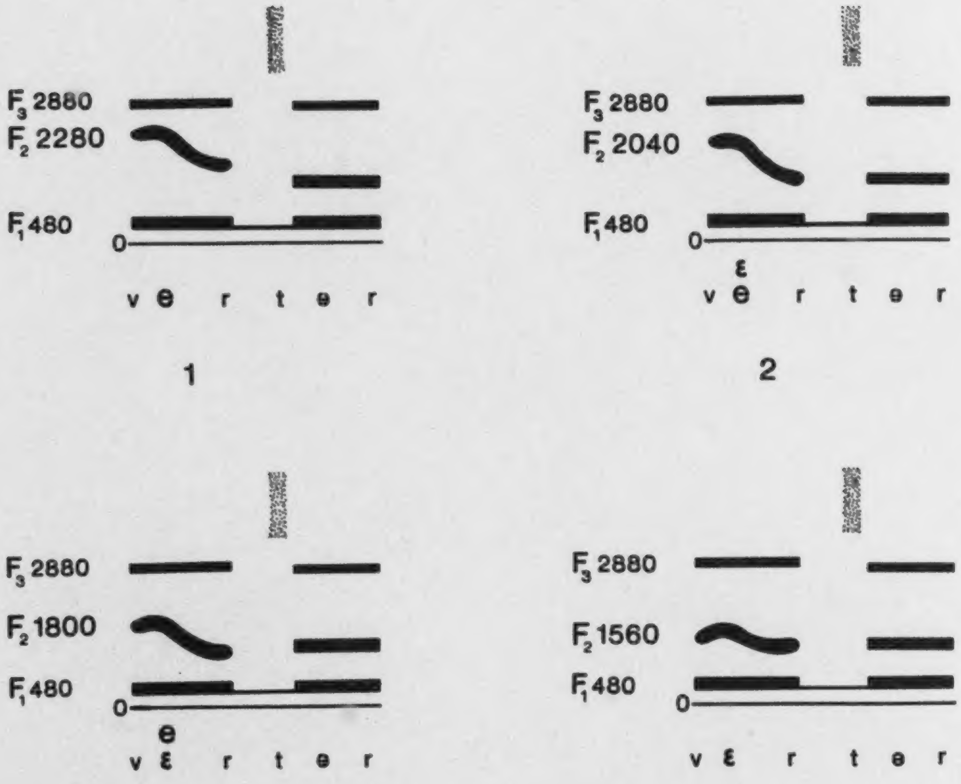
F$_2$ 2100/2400
F$_1$ 394/532
0
v e r t ə r
F$_3$ 2760
F$_2$ 1410/1610
F$_1$ 394/532
0
v ɛ r t ə r

COOPER PATTERNS


F$_3$ 2880
F$_2$ 2280
F$_1$ 480
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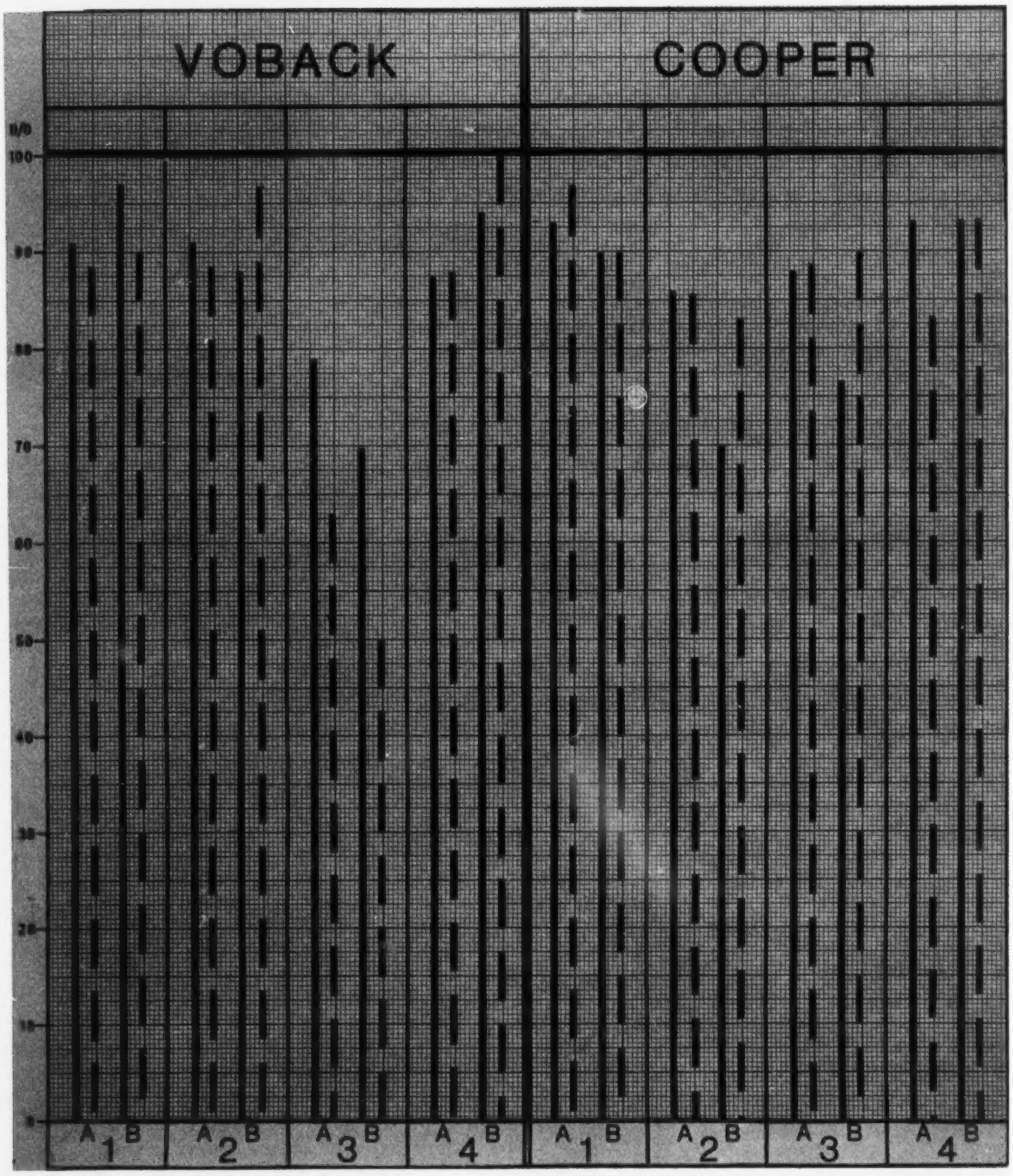
v e r t ə r
F$_3$ 2880
F$_2$ 2040
F$_1$ 480
0
ε
v e r t ə r
F$_3$ 2880
F$_2$ 1800
F$_1$ 480
0
e
v ε r t ə r
F$_3$ 2880
F$_2$ 1560
F$_1$ 480
0
v ε r t ə r

1 2

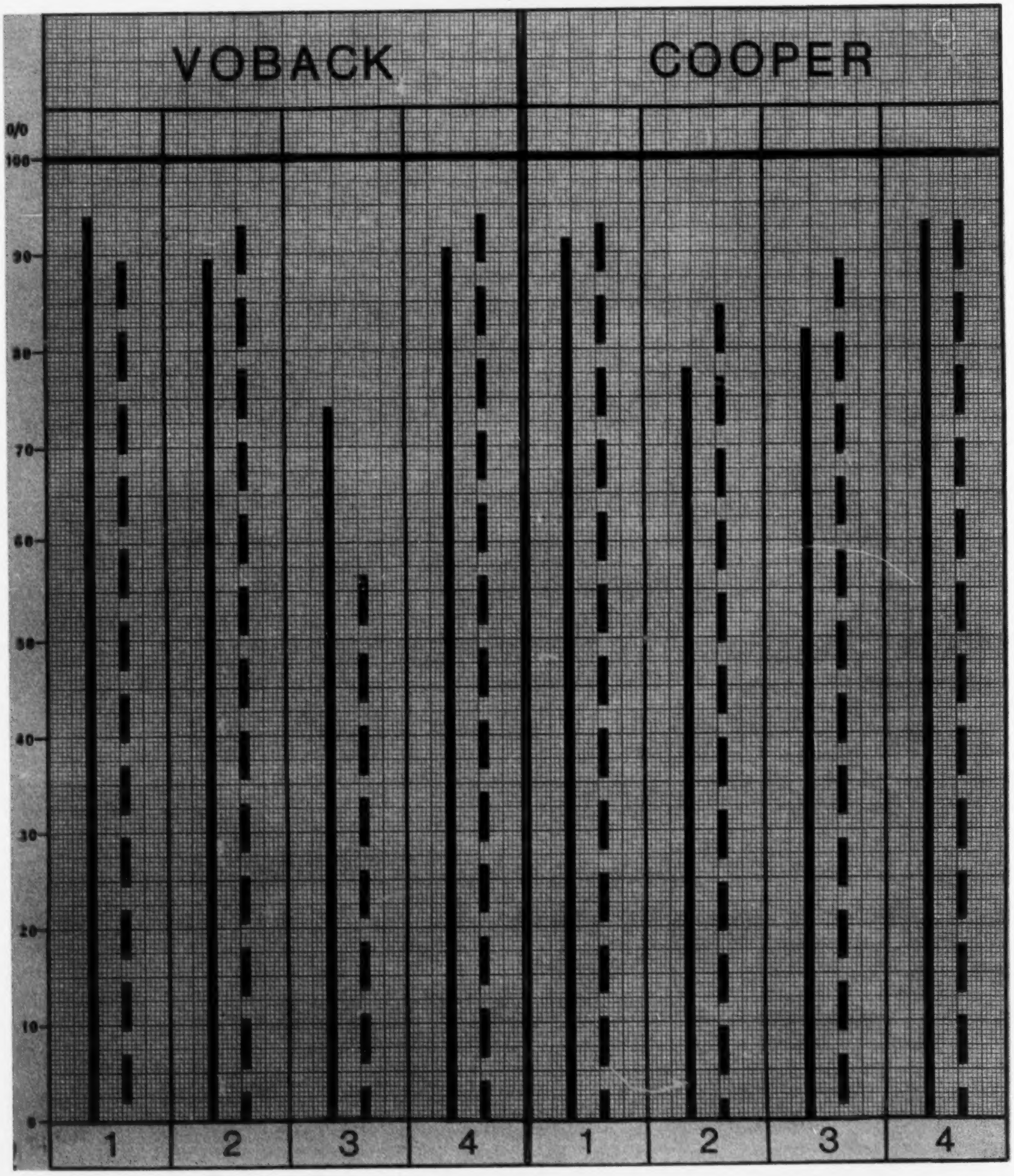
3 4

GRAPHIC REPRESENTATION OF PERCEPTION TEST RESULTS



Legend: Positive identification of [vertər/vɛrtər] by German (broken line) and American (solid line) naïve listeners. Results from pair-comparison (A) and single-stimulus-recognition (B) tests.

GRAPHIC REPRESENTATION OF PERCEPTION TEST RESULTS



Legend: Positive identification of [vertər/vɛrtər] by German (broken line) and American (solid line) naïve listeners.

COMPARATIVE PHONETIC STUDY
OF /l/ IN
AMERICAN-ENGLISH, FRENCH, GERMAN, AND SPANISH

Research techniques: For this study, we have adhered to the procedures developed by the late Professor Pierre Delattre. The point of departure was an exhaustive spectrographic study, the aim of which was to establish values for formant frequencies, transition rates, etc. The various ranges of values provided the basis for the next step, spectrographic speech synthesis, which consisted of producing series of synthetic speech stimuli with our 'MDGE' version of the Cooper Pattern Playback (Haskins Laboratories, Inc.). Each series contained systematic changes in the values of the parameters under consideration. Appropriate psychophysical tests were used to determine the optimum values. The articulatory aspect of the study was carried out with our cineradiographic equipment. X-ray motion picture films, with sound-track were made of a number of representative speakers articulating /l/ in a selection of phonetic contexts. The individual frames of these films were studied with our stop-motion projectors and correleated with sound spectrograms, made from the sound track, thus permitting an assessment of the relationship between articulatory configuration and acoustic output.

SPECTROGRAPHIC ANALYSIS

The corpus: In order to study the influence of vocalic context on /l/, we used a list of words--see below-- in which that consonant occurred in initial, intervocalic, and terminal positions, with as many different vowels as possible in each language. German provided the greatest variety of cases, followed by English and French, with Spanish showing a relatively poor array.

Initial /l/

	English	French	German	Spanish
/i/	leave	lit	liebe	lid
/I/	live		licht	
/e/	late	les	leere	le
/ɛ/	leg	lait	lärche	
/y/		lu	lügen	
/Y/			lücke	

/ø/		loess	lösen	
/ʌ,œ/	love	leur	löss	
/æ,a/	lack	la	lachen	la
/a/	large	las	laben	
/ɔ/	log	lobe	lotto	
/o/	loan	lot	lot	lo
/ʊ/	look		lust	
/u/	loom	loup	lug	luz

Intervocalic /l/

/i/	militia	milice	Miliz	milicia
/e/	melee	filé	belegen	Elena
/a/	ballade	ballade	ballade	balada
/o/	soloist	polo	Kolonne	colonia
/u/	Toulouse	Zulu	Lulu	Zulu

Terminal /l/

/i/	peal	vil	spiel	perfil
/I/	pill		dill	
/e/	pale		fehl	papel
/ɛ/	well	aile	Gesell	
/y/		bulle	Gefühl	
/Y/			Müll	
/ø/		meule	öl	
/ʌ,œ/	bull	gueule	Geröll	
/æ,a/	shall	balle	ball	coral
/a/	Kraal	mâle	Tal	
/ɔ/	doll	sol	zoll	bemol

/o/	coal	saule	Kohl	
/ʊ/	pull		Mull	
/u/	pool	boule	Stuhl	baul

The informants: For English, we used three male graduate students from the coastal region of Southern California; for French, two recently arrived Parisian students and one from Southern France; for German, three speakers of 'High German', one from Bremen, one from Westphalia and one from Central Prussia, all of them having been in America less than 5 years; and for Spanish, two Assistant Professors from UCSB and one engineer, all from the Buenos Aires area of Argentina.

The results: The principal acoustic characteristic of /l/, which it shares with /w, j, r/, is the degree of visibility of its formant structure. It is greater than that of other consonants yet less than that of vowels--on spectrograms this parameter appears as degree of darkness of the formants. This phoneme can be considered as part vowel, by virtue of its formants and steady states, and part consonant, by virtue of its rapid transitions. Its first two formants are in general very distinct, its F1 being always more intense than its F2. While these two formants are always in a mid-frequency range (below 2000 Hz, its higher formants show a high degree of complexity, as a function of phonetic context, Gunner Fant, in his Acoustic Theory of Speech Production (Stockholm, 1958), says that /l/ shows no less than 5 high formants in the 2250-5000 Hz range and that this accounts for that consonant's high resonant quality. Our own spectrograms have consistently shown at least three formants in this range. The following paragraphs contain a résumé of our numerical results in the form of average values for narrow-band (45Hz) spectrograms.

Initial /l/

First formant. As Fig. 1 shows, F1 is relatively low and stable for all four languages, its variability being limited to a range of 250 to 450 Hz. Within these limits, all four languages show a tendancy for that formant to follow F1 of the associated vowel. It is thus higher when /l/ is associated with /a/ than with any other vowel. However, it never reaches the frequency of F1 of the vowel, whose transitions towards /l/ are consequently always negative. When the relationship is considered from the point of view of the vowel, an influence in the opposite direction is noted: Any vowel associated with /l/ will have a higher F1 than when it is uttered in isolation. This observation had been made previously about English by Lehiste (Acoustical characteristics of selected English consonants, U. Mich., 1962, p. 70), and our own research has confirmed it for French, German and Spanish. Furthermore, Fant (op. cit., 167) has pointed out that the intelligibility of /l/ is enhanced when F1 of the associated vowel is somewhat higher than when that vowel is in isolation. Finally, within the range cited above, English sets itself apart from the three other languages in question by its slightly higher F1 for /l/.

Second formant. The essential difference between 'clear' and 'dark' /l/ is in the frequency of this formant, which is low in the latter and high in the former. The values for English /l/ are widely separated from the cluster of those for the three other languages. While the highest F2 value for English /l/ is only 1180 Hz, the minimum for French, German, and Spanish is in the 1450 Hz region. It is also noted that the F2 values for English are relatively stable, varying only over a 300 Hz range, while those of the other languages vary over a 500 Hz range. Within their respective ranges, the F2 values for /l/ in all four languages correlate almost perfectly with the frequency of F2 of the associated vowel--/l/ has the highest F2 values when associated with /i/ and the lowest when associated with /u/. Finally we can see from Fig. 1 that initial /l/ in Spanish is consistently less 'clear' than in either French or German.

Third formant. This formant is relatively stable in English as /l/ is associated with the various vowels. It is also stable in Spanish, (at a lower value than in English) with the front and central vowels, but drops off drastically with /o/ and especially with /u/. French and German exhibit strikingly similar apparently erratic patterns in this respect. The /l/ in these languages has a high F2 with the front spread vowels and central vowels but a low F2 with front rounded vowels and the back vowels. The unexpected dip is evidently a function of lip rounding and protrusion.

Intervocalic /l/

The values, shown in Fig. 2, show the same trends for F1 and F2 in all four languages studied, but the irregularities in F3, noted above for French and German /l/ in initial position, disappear.

First formant. F1 of English /l/ is again slightly higher than in the other languages, with French coming next. All four languages show its lowest values with the front and especially the back vowels, and its highest values with the central vowels.

Second formant. Again, this formant is dramatically lower in English than in the three other languages, varying from 1180 Hz with /i/ to 1100 Hz with /o/. The other languages show about the same values as they do for /l/ in initial position.

Third formant. F3 of /l/ in all four languages exhibit the same behavior in this position with the front vowels but diverge increasingly as the vowel goes toward /o/. The exceptionally low value for F3 in /polo/ is at variance with the results of earlier pilot studies conducted at this laboratory. The spectrogram shown in Fig. 3 shows the dramatic jump of F3 from its /o/-position to its /l/-position.

Terminal /l/

In spite of an apparent similarity between the results for /l/ in this position and those for initial and intervocalic /l/, a number of interesting differences emerge--see Fig. 4.

First formant. The values for French, German and Spanish are essentially the same as in initial position. The English values, however, are more widely separated from those of the other languages in this position than they are in initial position--they are approximately 100 Hz higher here than in initial position, but otherwise remain directly proportional to the aperture of the contiguous vowel.

Second formant. English /l/ also distinguishes itself dramatically from the 'clear' /l/ of the other languages by its very low F2, or viewed differently, by the closeness of its first two formants, which doubtedlessly accounts for its subjectively judged 'darkness', particularly in terminal position. The second formants of the /l/ of the three other languages continue to cluster, with Spanish the lowest of the three, and all of them show the influence of the contiguous vowel, having their highest values with /i/ and their lowest with /u/.

Third formant. The pattern of values for the four languages exhibits much the same characteristics as for /l/ in initial position, French and German /l/ having very low values when contiguous to front rounded vowels or to back vowels. The values for English remain fairly constant at a maximally high frequency position, while those for Spanish drop off sharply from /a/ to /u/.

In conclusion, all positions taken into consideration, English 'dark' /l/ differs from the 'clear' /l/ that characterizes the other languages studied in the following respects; listed in their order of importance:

1) a low frequency position for F2 (740 to 1180 Hz).
2) a slightly elevated frequency position for F1 (350 to 550 Hz)
3) an invariably high frequency position for F3 (2470 to 2710 Hz).

Finally, the great influence of the contiguous vowel on the formant structure of /l/ is clearly seen in Fig. 5, in which its F1 values have been graphically plotted against those of its F2, the former on the ordinate, the latter on the abscissa. The two inverted logarithmic scales are nowadays generally used to show the relationships between the acoustic signal and articulation. It is clear that since the /l/ requires only an apico-alveolar or apico-dental contact without lateral closure, the blade and back of the tongue are free to move about and are hence readily subject to the articulatory influences of contiguous phonemes. Thus as both varieties of /l/ are articulated with various vowels, their formant structure will approximate that of the vowels, and triangles will emerge closely resembling the well-known acoustic triangles for the vowels. It can be seen that the 'clearness' and 'darkness' of /l/ is a very relative thing, depending heavily on the character of the associated vowel. At most, all we can say is that the triangle for English 'dark' /l/ is lower and farther to the left, that is, closer to the back vowels than the 'clear' /l/ of the other languages. This strongly suggests that the perception of 'clearness' and 'darkness' operates on a co-articulatory basis with reference to the vowel in question. The consequences of this, as far as the teaching of foreign languages is concerned is that it must be presented and drilled in a variety of vocalic contexts--a single example cannot suffice.

SYNTHETIC SPEECH EXPERIMENTS

As in other experimental sciences, the results of our analysis, as given in the preceding section, must necessarily remain hypothetical until they are substantiated by synthesis and testing. Accordingly, the second phase of our /l/ study has consisted of using the results of our spectrographic analysis as a point of departure for synthesizing appropriate stimuli and testing them for identifiability and naturalness with phonetically uninitiated listeners. Two series of tests were developed, one for 'clear' /l/, one for 'dark' /l/. For each series, eighteen short 'pair-comparison' tests, each one containing four different stimuli were made up from tape recordings of the synthesized stimuli. In this type of test, the stimuli are presented in pairs, the total of which represents every possible combination. In our case, the subjects were asked to indicate which stimulus of each pair contained the more identifiable and the more natural /l/. The number of times a given stimulus was chosen, expressed either as a total or as a percentage, is a reliable measure of its quality. Two groups of subjects were used: Ten Americans who speak a more or less standard dialect were used to test the 'dark' /l/ stimuli, and ten French students, also representing a fairly standard dialect, were used to test the 'clear' /l/. The layouts of the two series of tests are shown in Tables 1 and 2, and the numerical results are shown in Figs. 6 and 7. Discussion of the results follows:

'Clear' /l/

First formant. Two observations emerge: (1) The best synthetic patterns require that the frequency of this formant vary with that of the contiguous vowel. As the figures show, listeners preferred a higher F1 for /la/ and /al/ than for /li/ and /il/. (2) The tests confirm the indications from spectrographs that, with respect to F1 frequencies, initial and terminal /l/ are practically identical.

Second formant. A glance at our graphs shows that our listeners preferred relatively high frequency positions for this formant. Although the positions indicated by our analysis ranged from 1550 to 1600 Hz, a frequency of 1800 Hz was preferred by 71 % of our subjects for /la/ and by 76 %. for /al/. On the other hand, for /lu/ and /ul/ our analysis had indicated F2 frequencies of about 1400 Hz, but our subjects preferred 1560 Hz for the two syllables respectively by 70 % and 71 % Still higher frequencies might have been preferred even more, but they were not tested because of their lack of relevancy to phonetic reality. These observations suggest that the French subjects are quite sensitive to the values of 'dark' /l/ and tend to shun them in favor of an exaggeratedly 'clear' /l/.

Third formant. Both initial and terminal /l/, with either /i/ or /a/, are preferred in the versions having the highest F3s (2760 Hz or 2880 Hz). With /u/, however, 'clear' /l/ behaves differently, our subjects preferring an F3 frequency of 1680 Hz in /lu/ (66 %) and 1920 Hz in /ul/ (70 %). Within the limits of our psychophysical tests, the results of our spectrographic analysis, which shows wide variations in F3 frequencies, are thus generally confirmed.

'Dark' /l/

First formant. For initial position, the psychophysical test for this formant confirmed that its most appropriate frequency position depends upon the spectrum of the contiguous vowel. Whereas in /læ / a frequency of 600 is preferred, the best values for /li/ and /lu/ appear to be approximately one channel, or 120 Hz, lower. For terminal position, the test confirms that the best F1 frequency positions, with the various vowels, are higher than for initial position.

Second formant. The variations of this formant were not judged to affect the quality of 'dark' /l/ appreciably--all were judged to be fairly satisfactory. From this we conclude that as long as F2 is in the general frequency range indicated by our spectrographic analysis, the /l/ will be acceptable to the American ear.

Third formant. In this case the highest frequencies used were the preferred ones (2760 to 2880 Hz), whereas spectrographic analysis had indicated a somewhat lower value (2700 Hz).

The net result of all the tests is that the hypotheses that emerged from our spectrographic analysis were generally confirmed.

CINERADIOGRAPHIC STUDY

The experimental conditions for this phase of the study are as follows: From the pool of subjects used in the spectrographic and psychophysical work described above, we chose the speaker of each of the four languages that we judged to have the most representative accent. Cineradiographic films at right angles to the saggital plane were made from the subject's right side, as he articulated the test items--see below. Simultaneously, his acoustic output was recorded on magnetic tape. The test items in the four languages are shown in Table 3. They are all meaningful words, the total array of which provides a number of phonetic contexts for the /l/, as follows: a) initial, intervocalic, and final /l/ juxtaposed to the three vowels common to all four languages and forming the apexes of the vowel triangle (/i, a, u/); b) post-consonantal, after /p, m, t, k/, in most cases followed by /a/; and c) pre-consonantal, with the same consonants and in most cases preceded by /a/. Typical sequences in the four languages are shown in Figs. 8-39. The results are as follows:

Initial position. In /li/, French and Spanish show marked anticipation of the vowel, by the high position of the tongue even before apico-alveolar contact is made, while in English the tongue is quite low at the corresponding point in the articulatory sequence. Furthermore, the profile of the tongue is concave, and its root is in close approximation to the posterior pharyngeal wall in English (giving the /l/ its 'dark' quality), while in French and German, it is rather convex and thrust forward. In Spanish the tongue is also in a forward position, but its profile exhibits a slight concavity. Finally, in English, the tongue is always in motion, while the three other languages appear to have a brief steady-state. In /la/, differences of point of articulation show up very clearly. English /l/ exhibits a post-alveolar retroflex position, with the very tip of the tongue playing the major role, while in the other languages contact is made more with the blade at a point between the alveolar ridge and the gum line of the upper incisors. The sequence for /lu/ dramatically shows the great amount of anticipation of the vowel in French and German in the amount of lip projection even during the /l/, while in English (and to a lesser degree also in Spanish), this is not the case. It must be noted here that in Argentinian Spanish, a lip rounding in such contexts is largely a function of idiolect.

Intervocalic position. Our films have shown /l/ in this position to behave in a manner identical to that of initial position. One additional observation was possible here, namely that the 'hold' portion of /l/ is somewhat shorter in German and Spanish than it is in either English or French. Aside from that, we again note the characteristically low tongue position for English, its post-alveolar point of articulation, the concavity of English and Spanish tongue profiles, and the marked lip projection during the articulation of /l/ in French and German.

Terminal position. In English, French, and Spanish, /l/ is articulated much in the same way in /li/ as it is in /il/. A comparison of the /l/ in English lead and peal shows the same post-alveolar, retroflex, apical articulation, the same tongue concavity, and the same enlargement of the back of the tongue, while French and Spanish /l/ in both positions show an alveolar point of articulation and a large posterior cavity due to tongue fronting. The only important articulatory differences between these two languages is the convexity of the tongue for French and the slight concavity for Spanish, and the progressive lowering of the tongue in French. German /l/ sets itself apart from the other languages in this context: Although Spanish and German /l/ are articulated in the same manner in initial position with /i/, they are quite different in terminal position. It is much more posterior in Spiel than it is in liebe, and the tongue profile, which is convex in the former, becomes concave and slightly retroflex in the latter. In the articulation of /al/, e.g., Ball, and /ul/, e.g., Stuhl, German exhibits the same articulatory characteristics as in /il/, with the addition of anticipating lip rounding in /ul/.

Post-consonantal /l/

Whereas the preceding film sequences showed maximal vowel anticipation for French and Spanish and minimal vowel anticipation for English and German, as far as tongue position is concerned, the sequences with post-consonantal /l/ show maximal consonant anticipation for English and German and practically none for French and Spanish. In English and German, the apico-alveolar contact for /l/ is made almost simultaneously with the separation of the lips after /p/, while in French and Spanish the tongue tip is at the corresponding moment still at rest behind the incisors and has not begun to emerge from the mass of the tongue. The sequence /tl/ is slightly complicated by the fact that the stop is alveolar in English and German and dental in French and Spanish. Furthermore, our German speaker's /t/ became voiced by assimilation to /l/. As far as the actual articulation of /l/ is concerned, the characteristic convexity of French and German, as opposed to the marked concavity of English and the slight concavity of Spanish, is quite visible. Furthermore, the contrasting points of articulation for English and German (post-alveolar), on the one hand, and for French and Spanish (pre-alveolar), on the other are clearly differenciated. Finally, the vowel anticipation habit of the French is seen in the opening of the velo-pharyngeal port which occurs almost simultaneously with the /l/ release. In /kl/, as articulated by our American and German speakers, the apico-alveolar contact for /l/ is made while the dorso-velar occlusion for /k/ is still in effect. Aside from this, the articulations exhibit much the same characteristics as in /pl/, except that the German articulation was extremely rapid in this instance.

Pre-consonantal /l/

The results for /l/ in this position were unexpected in several respects, and they show rather marked differences among the four languages in question. In English we found no elevation of the tongue tip toward the alveolar region. Instead, it remained passively behind the lower incisors for the entire duration of the 'hold' interval of the /l/, not participating in any way in the articulation of that consonant. On the other hand, the body of the tongue assumed the characteristic concave profile, while the back rose to a relatively high position. This produces a rather large front resonating cavity, which accounts for the very low second formant of English /l/. The French /l/ in this context turned out to be similar to what we had observed in other positions, with apico-alveolar contact together with a convex profile for the body. German /l/ is quite different from either of the versions just described, having a cacuminal articulation with an apico-alveolar contact almost to the anterior limit of the palate. As a consequence the post-articulatory cavity is maximally reduced, which raises F2 to the 1900 Hz region. Also, a high degree of anticipation of the terminal consonant is evident, particularly before /p/. Here, the lips make contact even before the tongue tip has resumed its low position behind the lower incisors. Finally, Spanish /l/ in this context is almost identical with French /l/, except for the slightly concave profile noted earlier. The characteristics of pre-consonantal /l/ in the four languages are most easily compared in the articulation of /lm/. In English, as we have pointed out, the tongue tip is uninvolved. The concave profile of the body is abandoned at the moment the lips begin to close for /m/. The velopharyngeal port opens quite rapidly and much sooner in both English and German, in anticipation of the nasal mode of /m/, than it does in either French or Spanish. In this sequence, German shows its relatively very posterior point of articulation, while French and Spanish /l/s are maximally anterior (dental), the latter differing only in their respective convex and concave profiles--see above.

GENERAL CONCLUSIONS

1) American English /l/ is subjectively termed 'dark' because of its low second formant and the close approximation of its F1 and F2, resulting in a /ɯ/-like color during its steady-state. Its point of contact is considerably more posterior than in French or Spanish, and the tongue profile is markedly concave. Before another consonant, except another alveolar, it is completely

vocalized, no apico-alveolar contact taking place.

2) French and Spanish /l/s, termed 'clear' because of their relatively high F2 and the wide separation of their first two formants have almost identical articulations except for their tongue profile, which is convex for the former and slightly concave for the latter. Their articulation is dental.

3) French, German and Spanish /l/s are similar in many respects, in initial, intervocalic and post-consonantal position.

4) German /l/ is cacuminal (retroflex) in terminal position and when it is pre-consonantal.

Table 1

FORMANT FREQUENCIES FOR 'CLEAR' - /l/

Variations of Fl

	initial /l/			final /l/		
	li	la	lu	il	al	ul
Fl	120	120	120	120	120	120
	240	240	240	240	240	240
	360	360	360	360	360	360
	480	480	480	480	480	480
F2	1920	1680	1440	1920	1680	1440
F3	2640	2640	1920	2640	2640	2640
Variations of F2						
Fl	360	360	360	360	360	360
F2	1680	1440	1200	1680	1440	1200
	1800	1560	1320	1800	1560	1320
	1920	1680	1440	1920	1680	1440
	2040	1800	1560	2040	1800	1560
F3	2640	2640	1920	2640	2640	1920
Variations of F3						
Fl	360	360	360	360	360	360
F2	1920	1680	1440	1920	1680	1440
F3	2520	2520	1680	2520	2520	1680
	2640	2640	1800	2640	2640	1800
	2760	2760	1920	2760	2760	1920
	2880	2880	2640	2880	2880	2640

Table 2

FORMANT FREQUENCIES FOR 'DARK' - /l/

Variations of F1

	initial /l/			final /l/		
	li	læ	lu	il	æl	ul
F1	120	240	120	240	360	240
	240	360	240	360	480	360
	360	480	360	480	600	480
	480	600	480	600	720	600
F2	1200	1200	1080	1200	1080	960
F3	2640	2640	2640	2640	2640	2640

Variations of F2

	li	læ	lu	il	æl	ul
F1	360	480	360	480	600	480
F2	960	840	720	960	840	720
	1080	960	840	1080	960	840
	1200	1080	960	1200	1080	960
	1320	1200	1080	1320	1200	1080
F3	2640	2640	2640	2640	2640	2640

Variations of F3

	li	læ	lu	il	æl	ul
F1	360	480	360	480	600	480
F2	1200	1200	1080	1080	1080	960
F3	2520	2520	2520	2520	2520	2520
	2640	2640	2640	2640	2640	2640
	2760	2760	2760	2760	2760	2760
	2880	2880	2880	2880	2880	2880

Table 3

TEST ITEMS FOR SPECTROGRAPHIC STUDY OF /l/

Initial /l/

	English	French	Germand	Spanish
/i/	lead	ligue	Liebe	liga
/a-æ/	lack	lac	lachen	laca
/u/	loop	loupe	Lug	luz

Intervocalic /l/

/i/	militia	milice	Miliz	militia
/a-æ/	ballade	ballade	Ballade	balada
/u/	soloist	Zulu	Lulu	Zulu

Final /l/

/i/	peal	pile	Spiel	mil
/a-æ/	shall	bal	Ball	sal
/u/	pool	poule	Stuhl	Tul

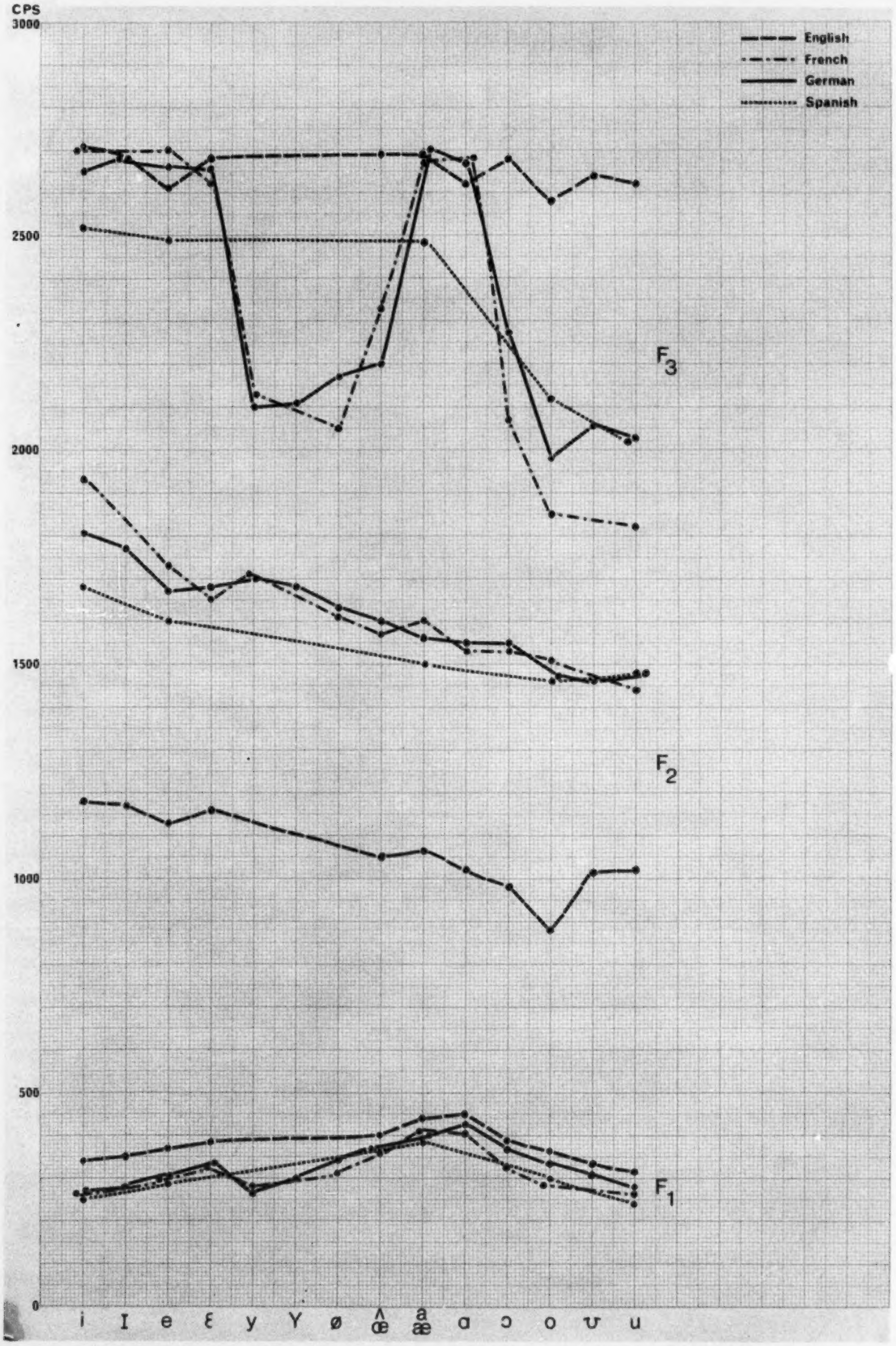
Post-Consonantal /l/

After				
/p/	plash	place	Platt	plaza
/t/	Atlantic	atlante	atlantisch	atlantico
/k/	clash	classe	Klasse	claro

Pre-Consonantal /l/

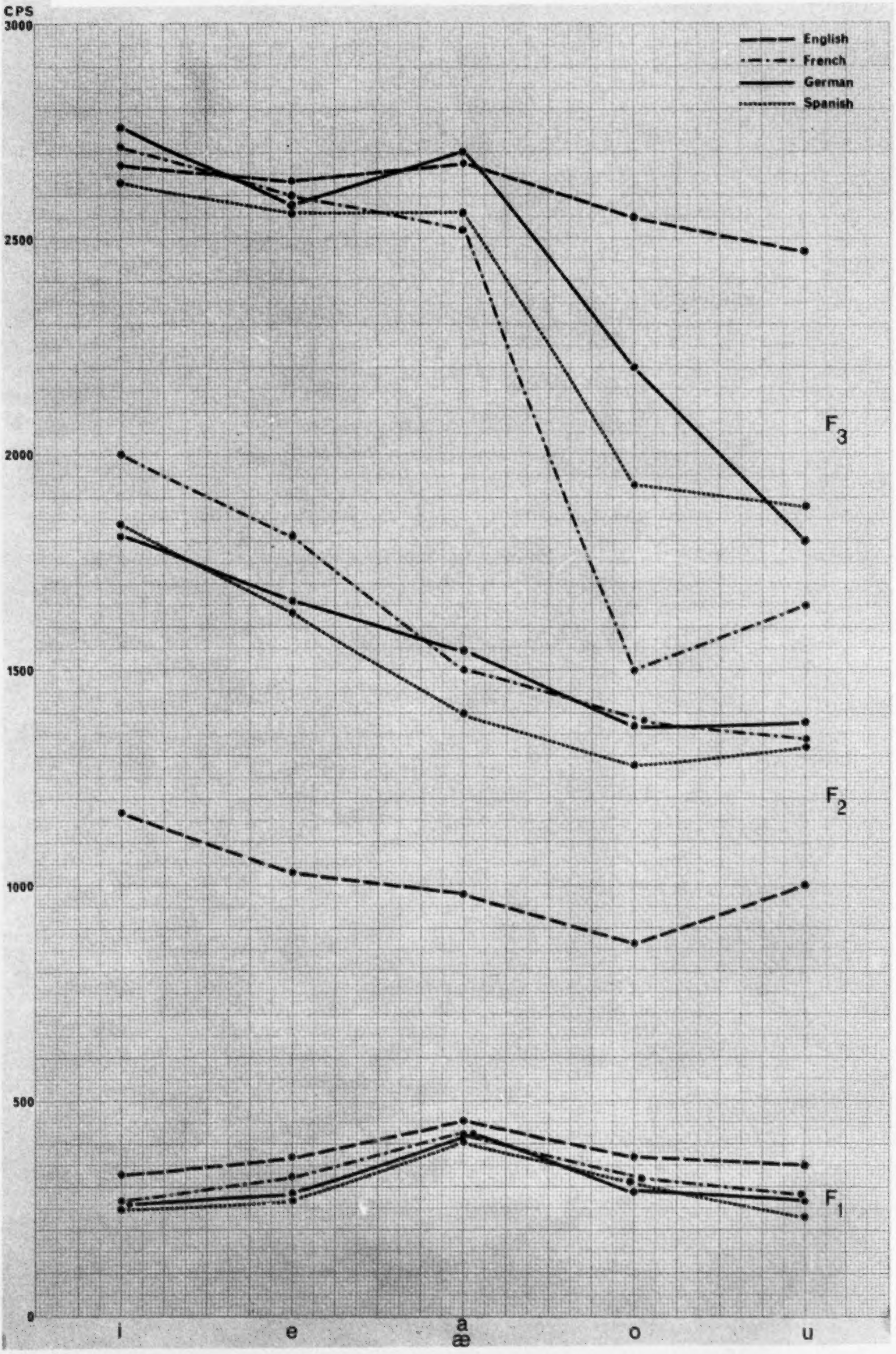
Before				
/p/	alp	alpe	alp	alpes
/t/	shalt	halte	alt	alto
/k/	talc	talc	Falk	talco
/m/	film	film	film	filme

Fig. 1



FORMANT FREQUENCIES FOR INITIAL-/l/ IN FOUR LANGUAGES

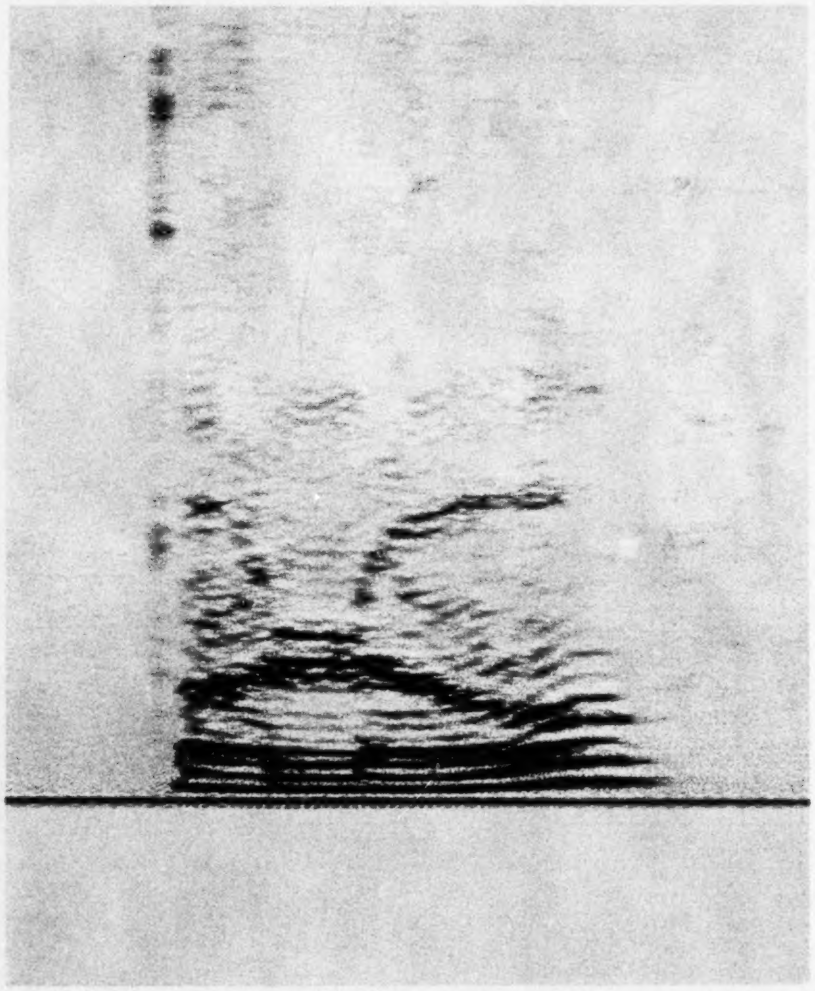
Fig. 2



FORMANT FREQUENCIES FOR INTERVOCALIC-/l/ IN FOUR LANGUAGES

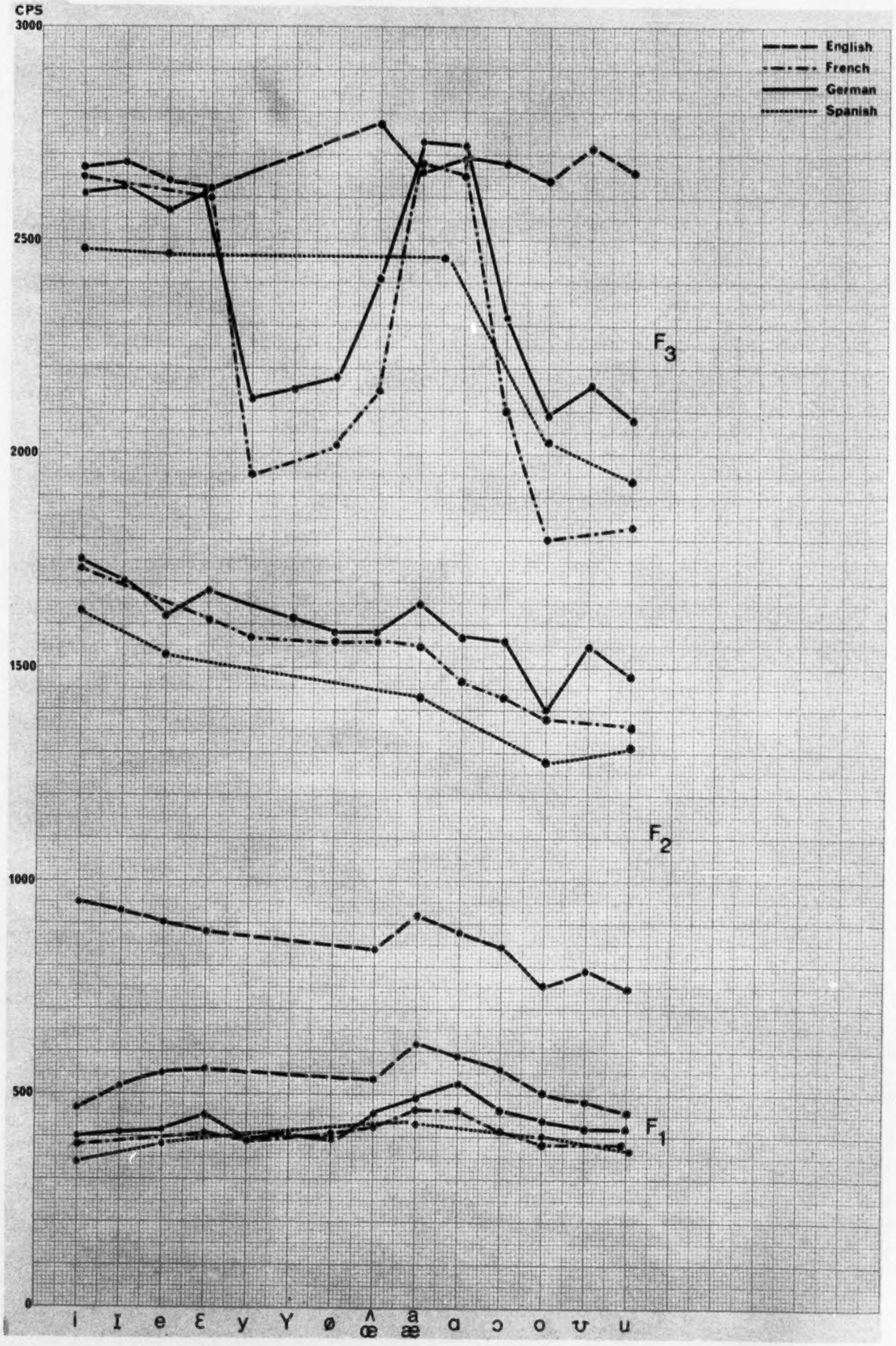
Fig. 3

WIDE BAND SPECTROGRAM OF /polo/ WITH 'CLEAR' /l/



N.B. The sweeping F3 transitions to and from the low steady-state frequency are clearly visible here.

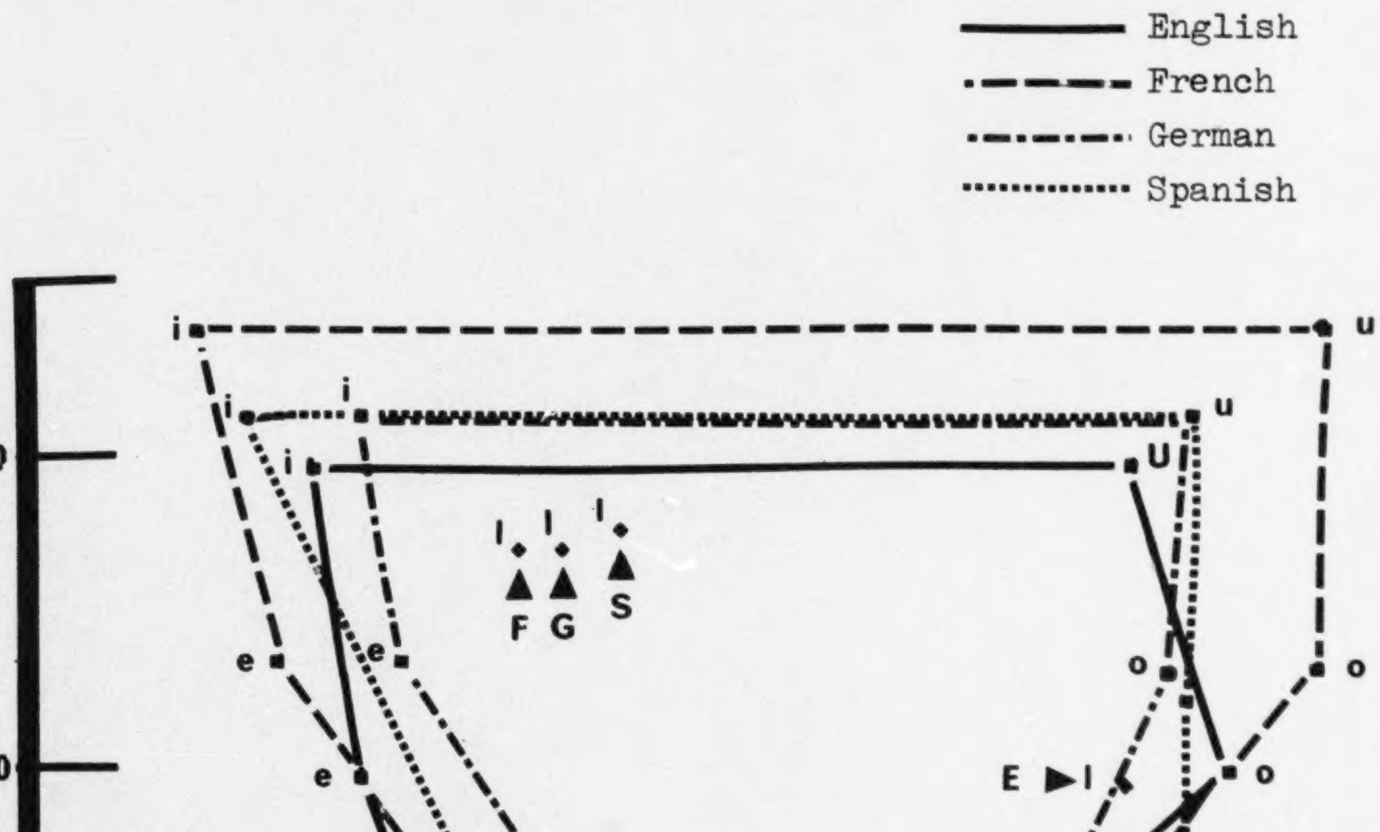
Fig. 4



FORMANT FREQUENCIES FOR FINAL-/l/ IN FOUR LANGUAGES

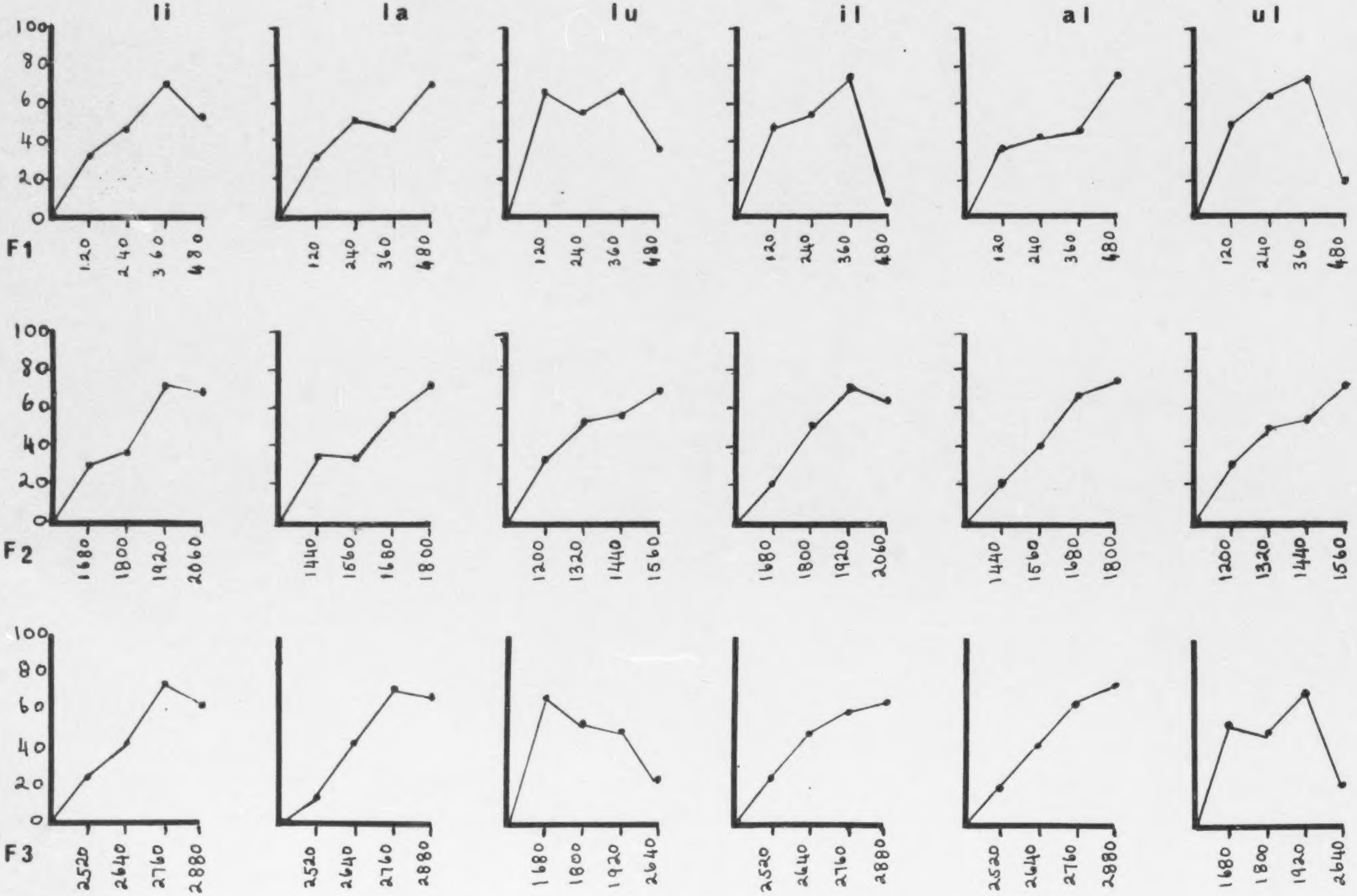
Fig. 5

FORMANT FREQUENCIES OF /l/ WITH FIVE VOWELS IN FOUR LANGUAGES



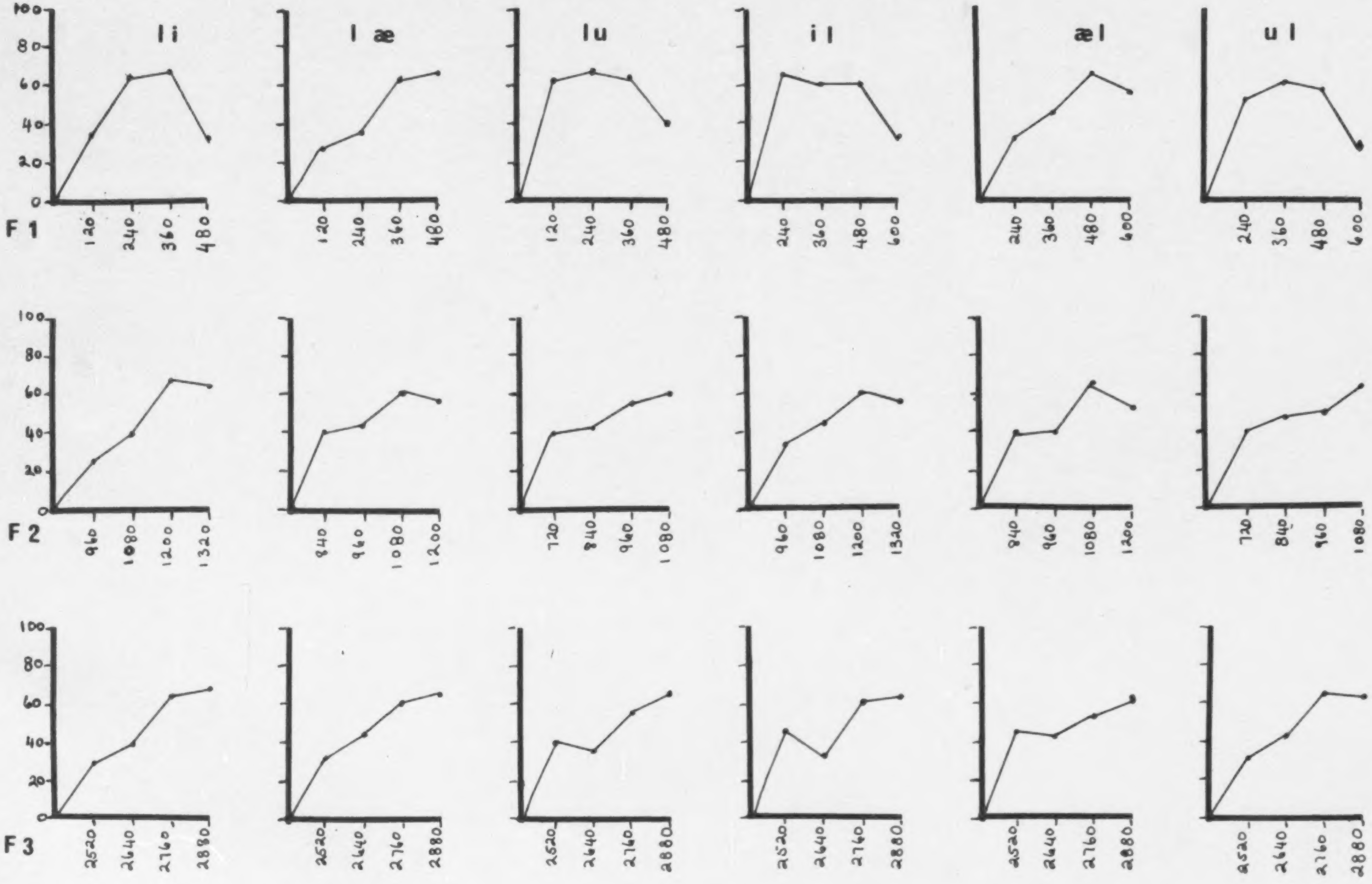
CLEAR /l/ FORMANT FREQUENCIES fig. 6

percent of preferences

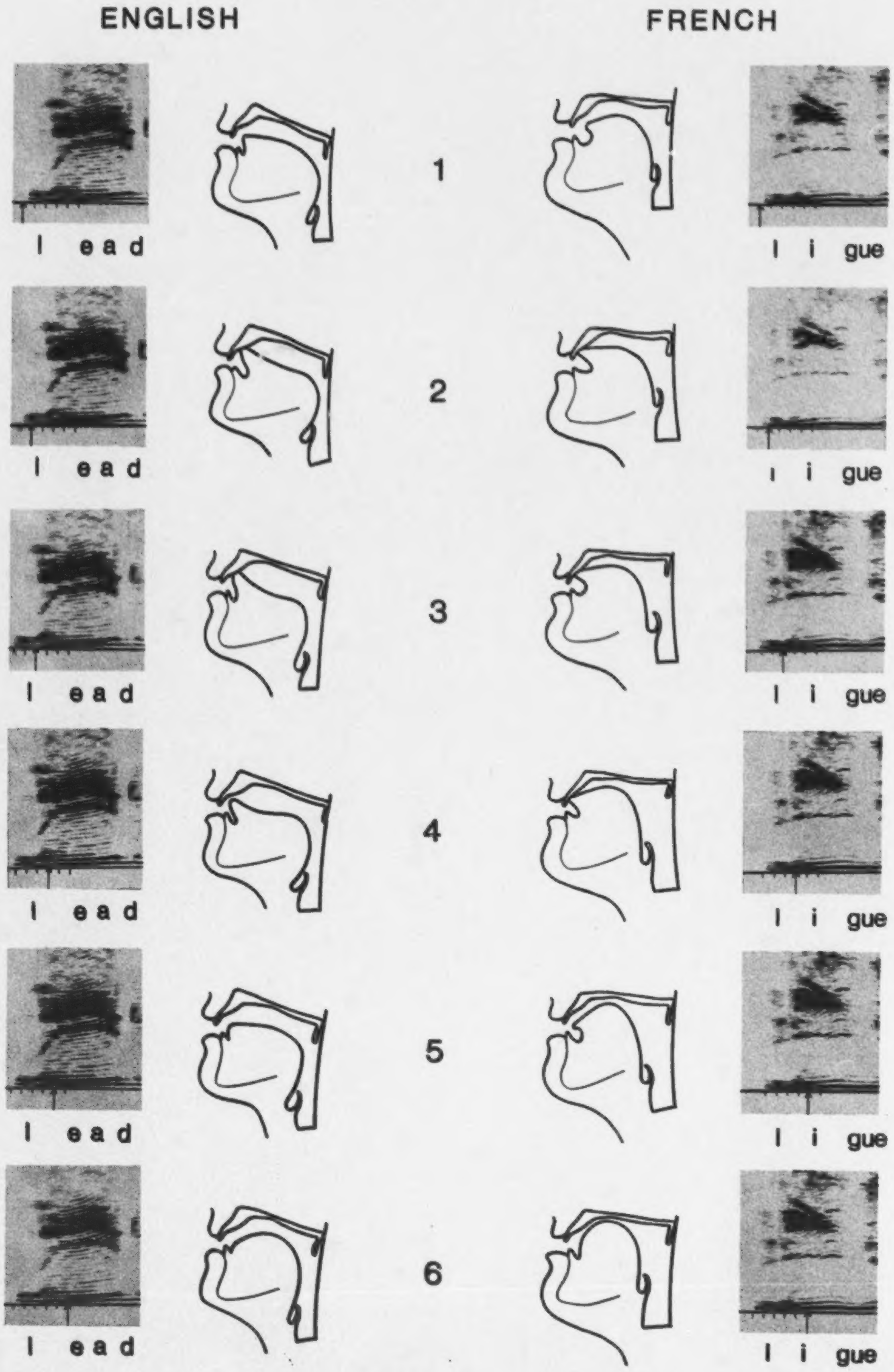


DARK /l/ FORMANT FREQUENCIES Fig. 7

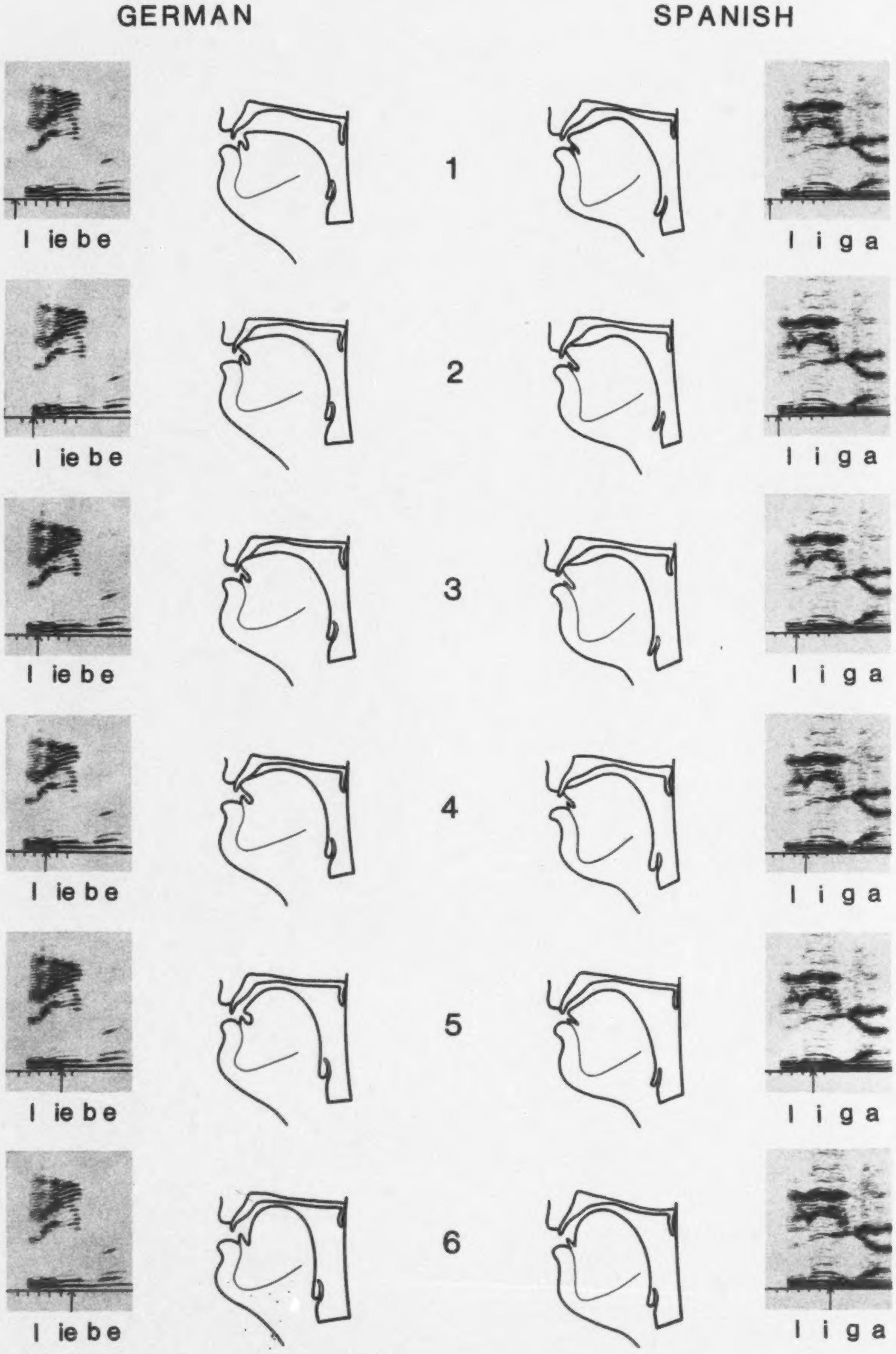
percent of preferences



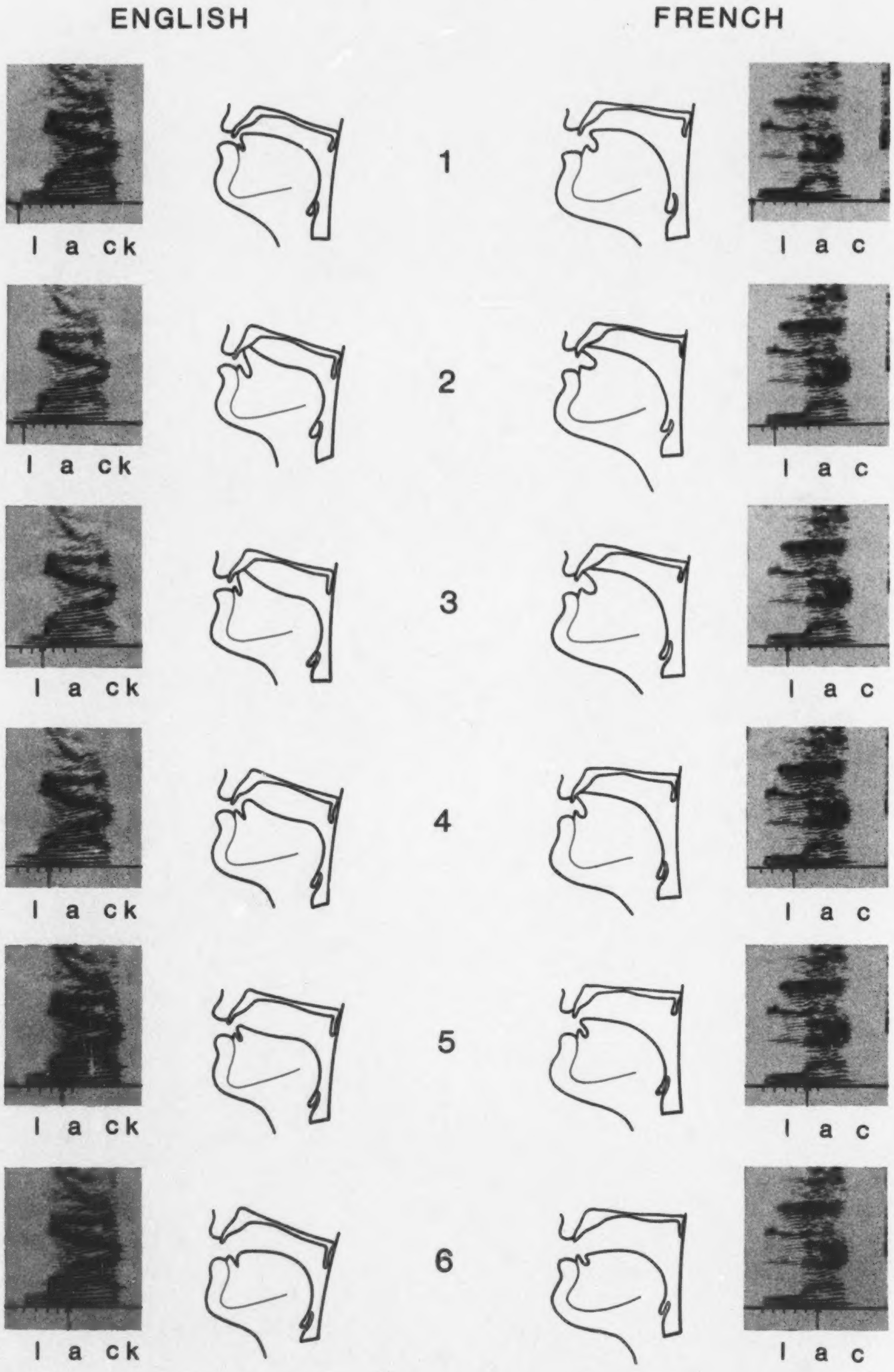
INITIAL /l/


ENGLISH
FRENCH
1
2
3
4
5
6
l ead
l i gue

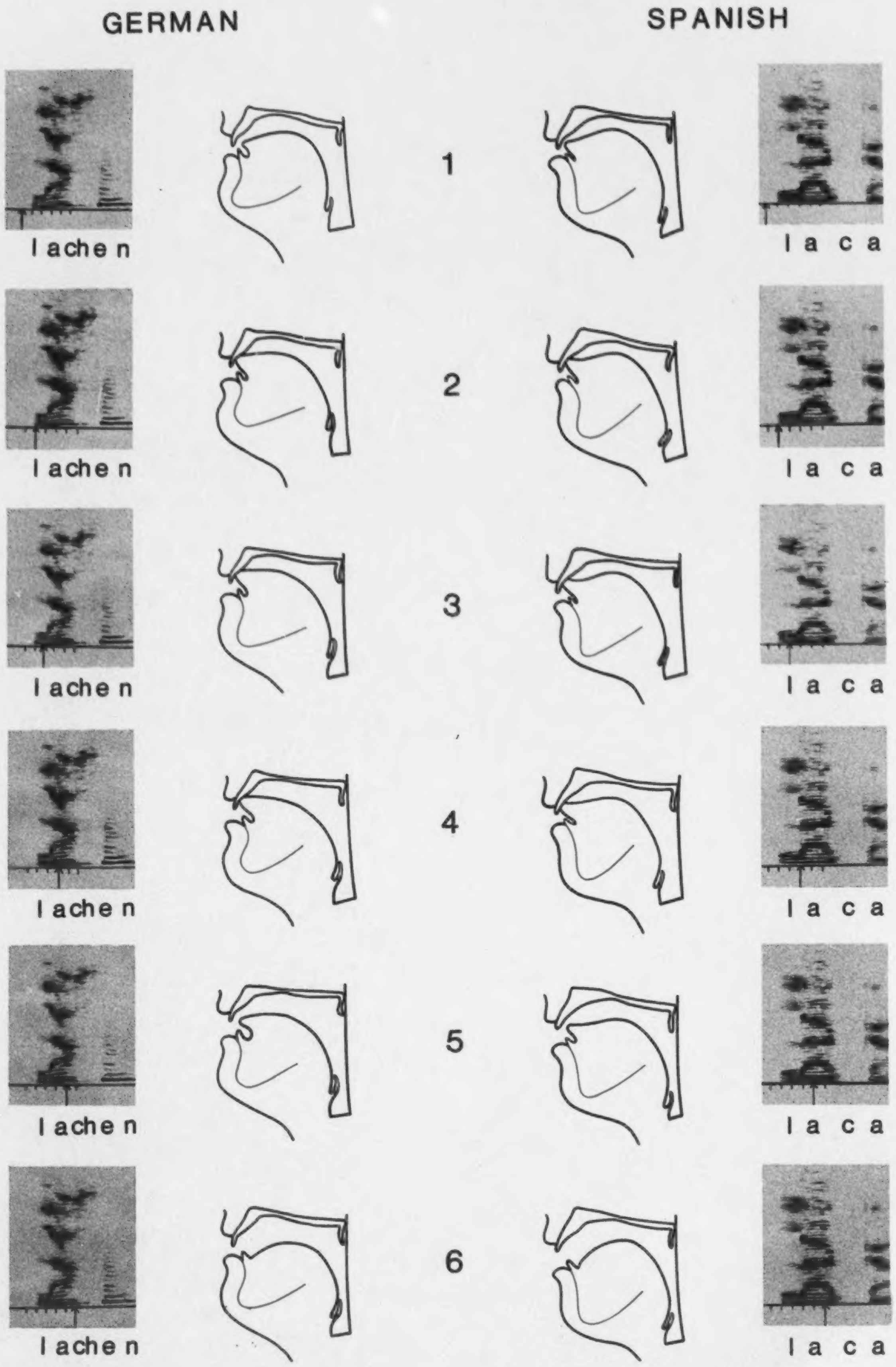
INITIAL /l/


GERMAN
SPANISH
1
l ie be
l i g a
2
l ie be
l i g a
3
l ie be
l i g a
4
l ie be
l i g a
5
l ie be
l i g a
6
l ie be
l i g a

INITIAL /l/


ENGLISH
FRENCH
1
l a ck
l a c
2
l a ck
l a c
3
l a ck
l a c
4
l a ck
l a c
5
l a ck
l a c
6
l a ck
l a c

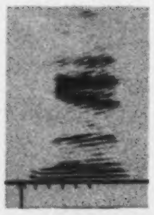
INITIAL /l/

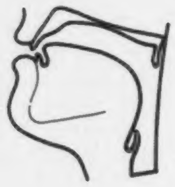

GERMAN
SPANISH
1
l ache n
l a c a
2
l ache n
l a c a
3
l ache n
l a c a
4
l ache n
l a c a
5
l ache n
l a c a
6
l ache n
l a c a

INITIAL /l/

ENGLISH

FRENCH


l oo p



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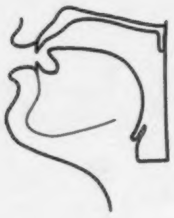
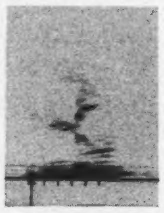
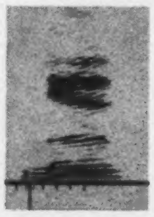
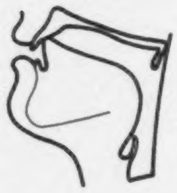



l ou pe


l oo p



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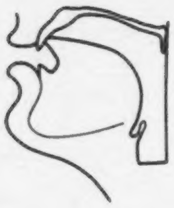
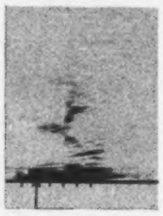
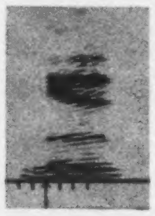
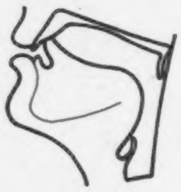



l ou pe


l oo p



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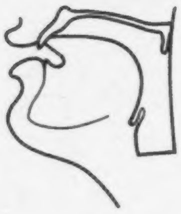
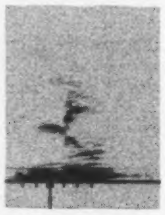
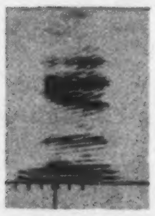
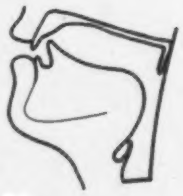



l ou pe


l oo p



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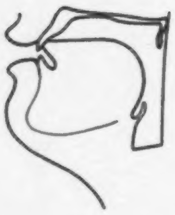
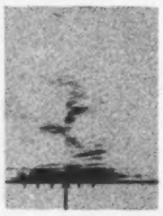
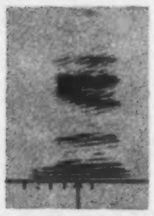
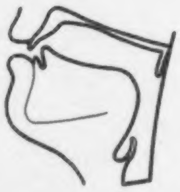



l ou pe


l oo p



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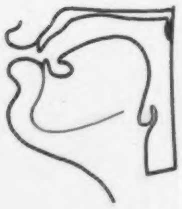
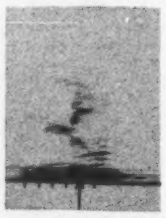
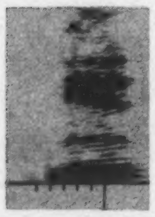
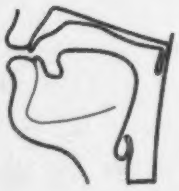



l ou pe


l oo p



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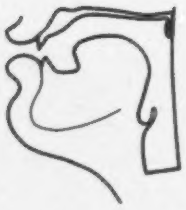
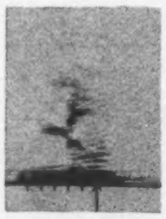
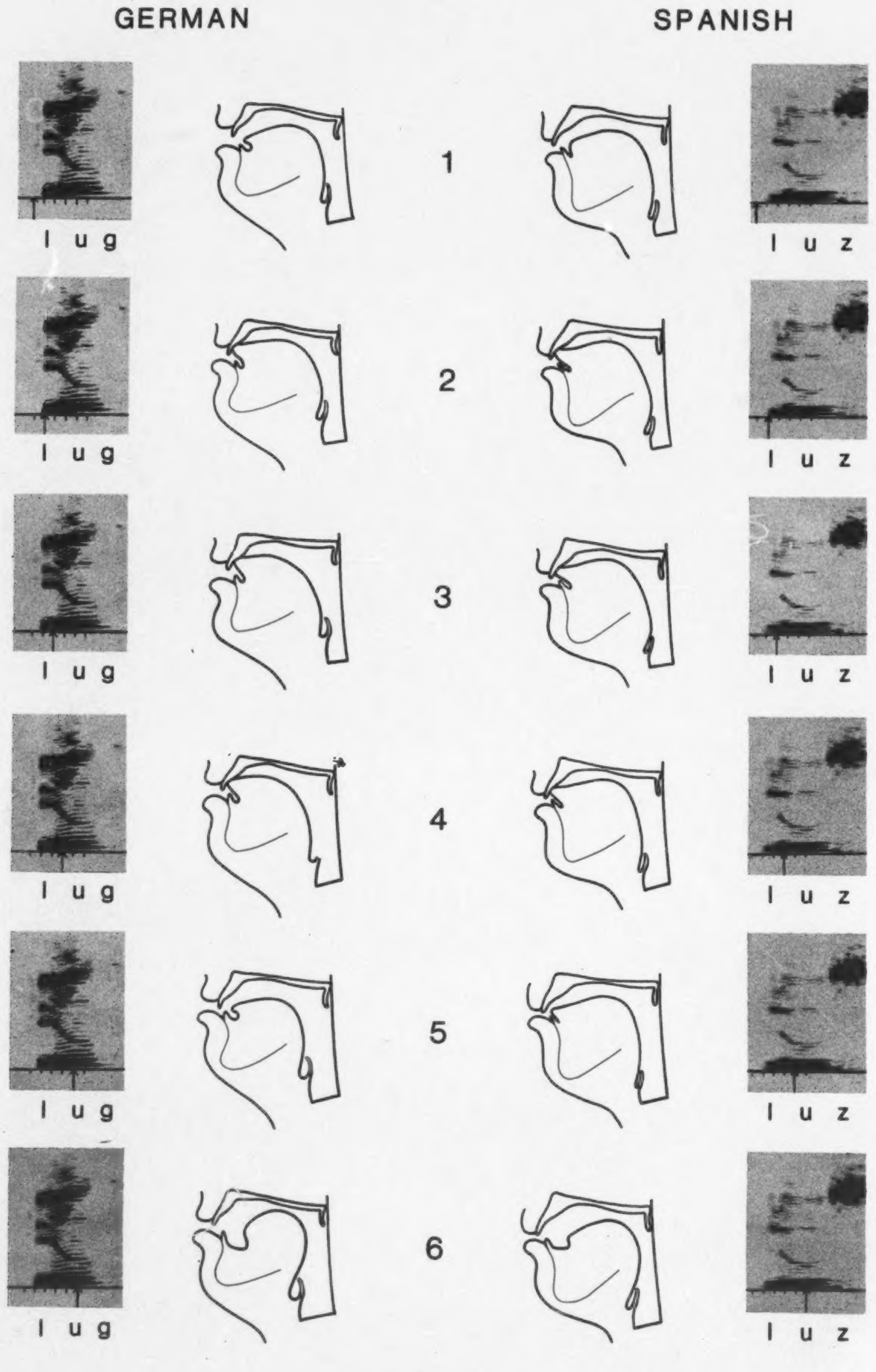
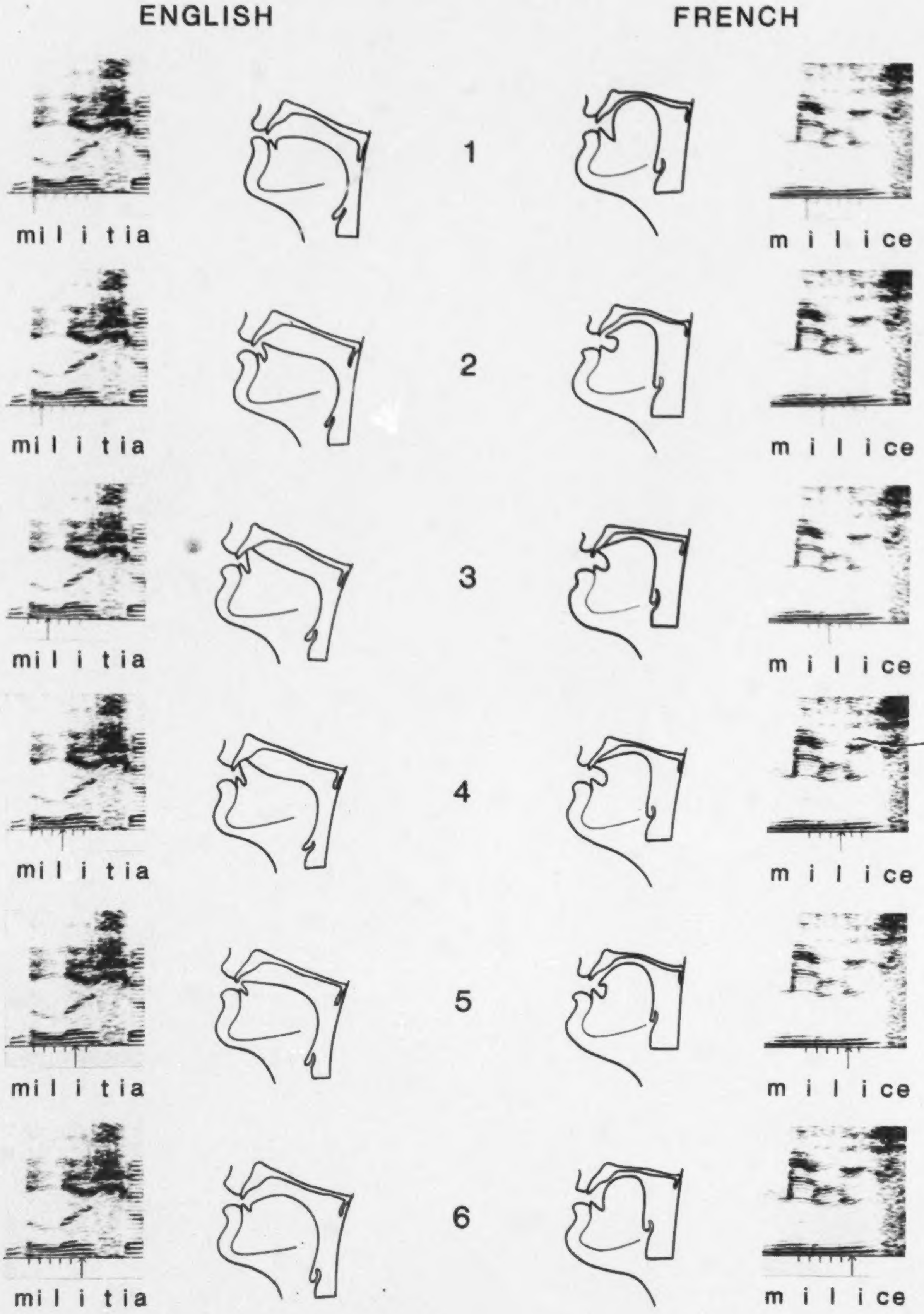



l ou pe

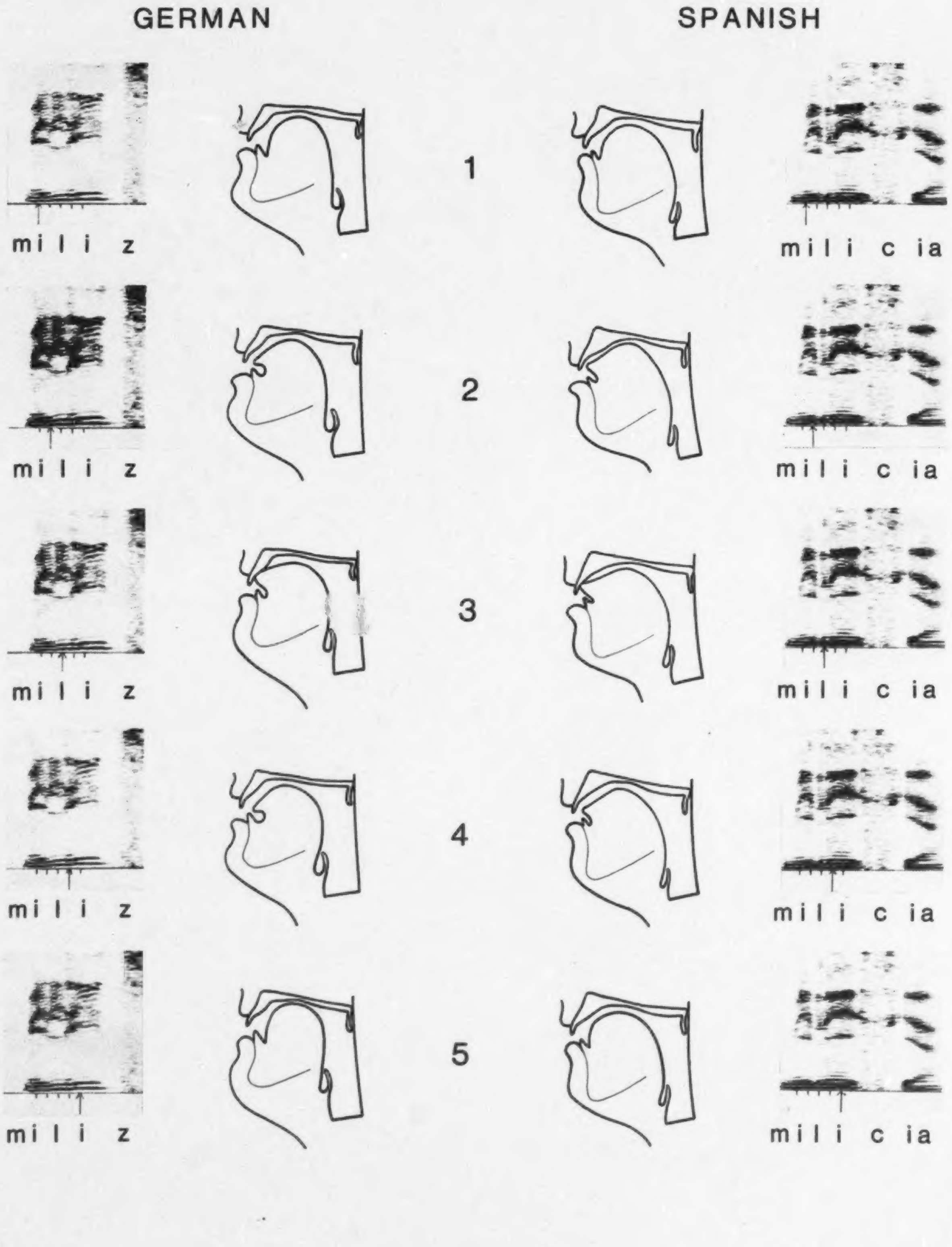
INITIAL /l/


GERMAN
SPANISH
1
2
3
4
5
6
l u g
l u z

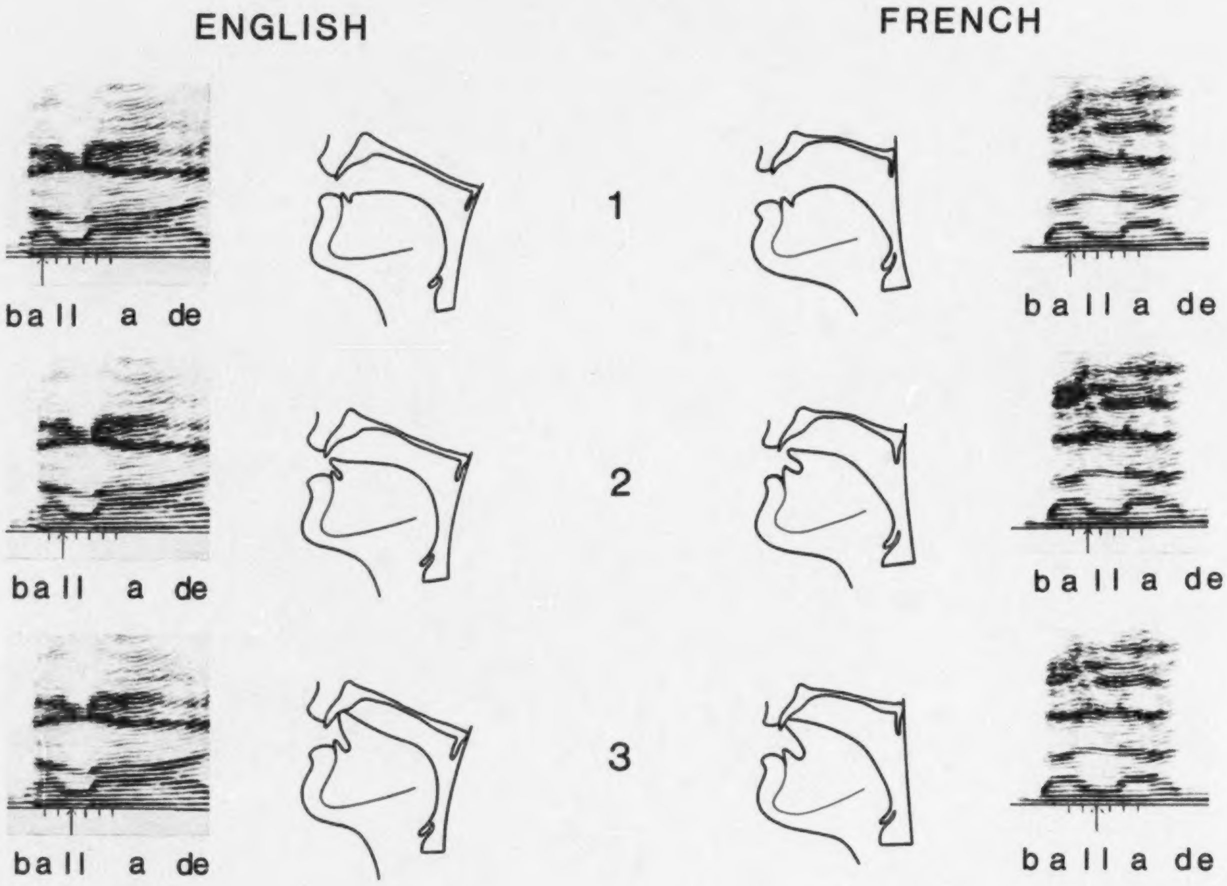
INTERVOCALIC /l/



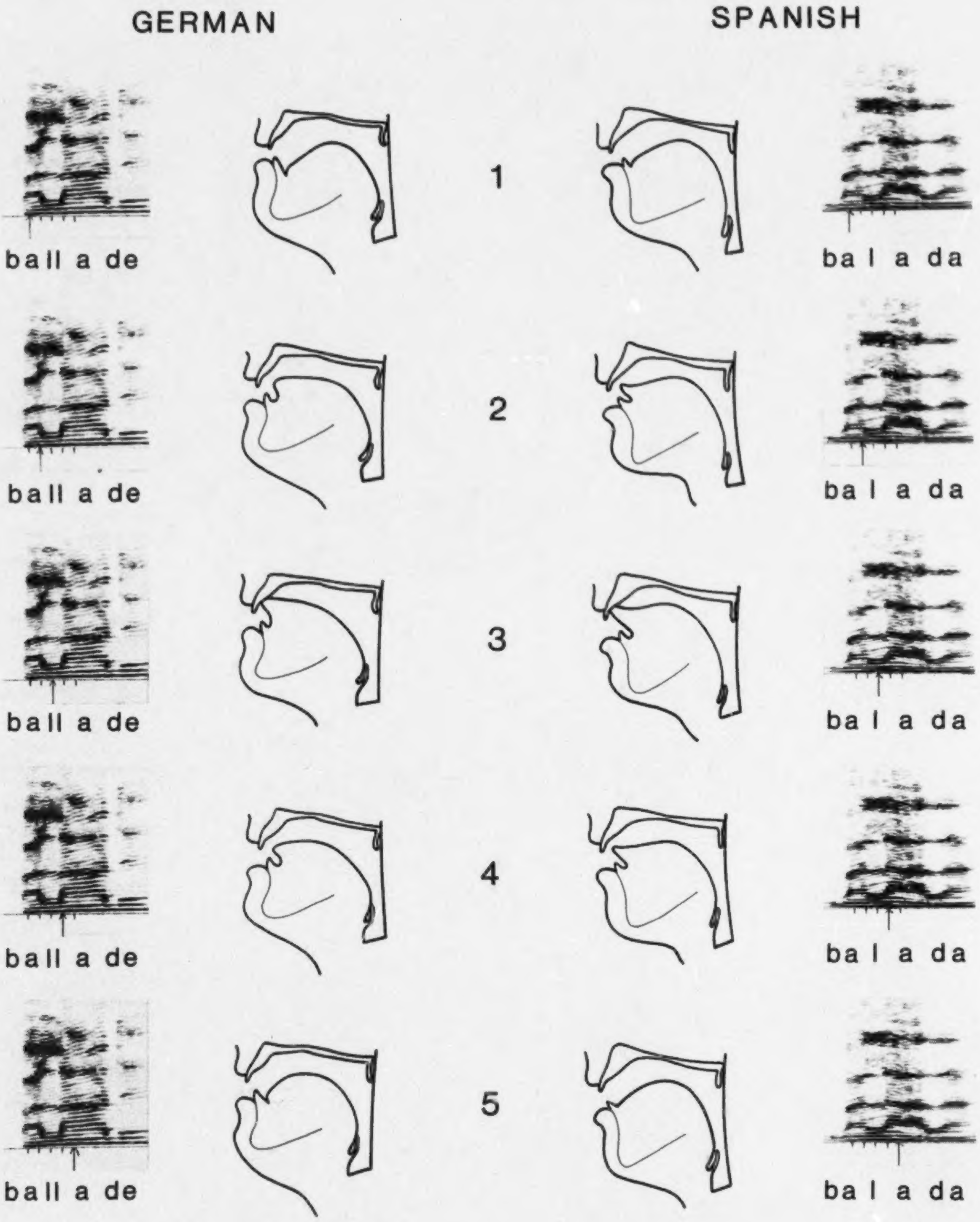
INTERVOCALIC /l/


GERMAN
SPANISH
mi l i z
1
mil i c ia
mi l i z
2
mil i c ia
mi l i z
3
mil i c ia
mi l i z
4
mil i c ia
mi l i z
5
mil i c ia

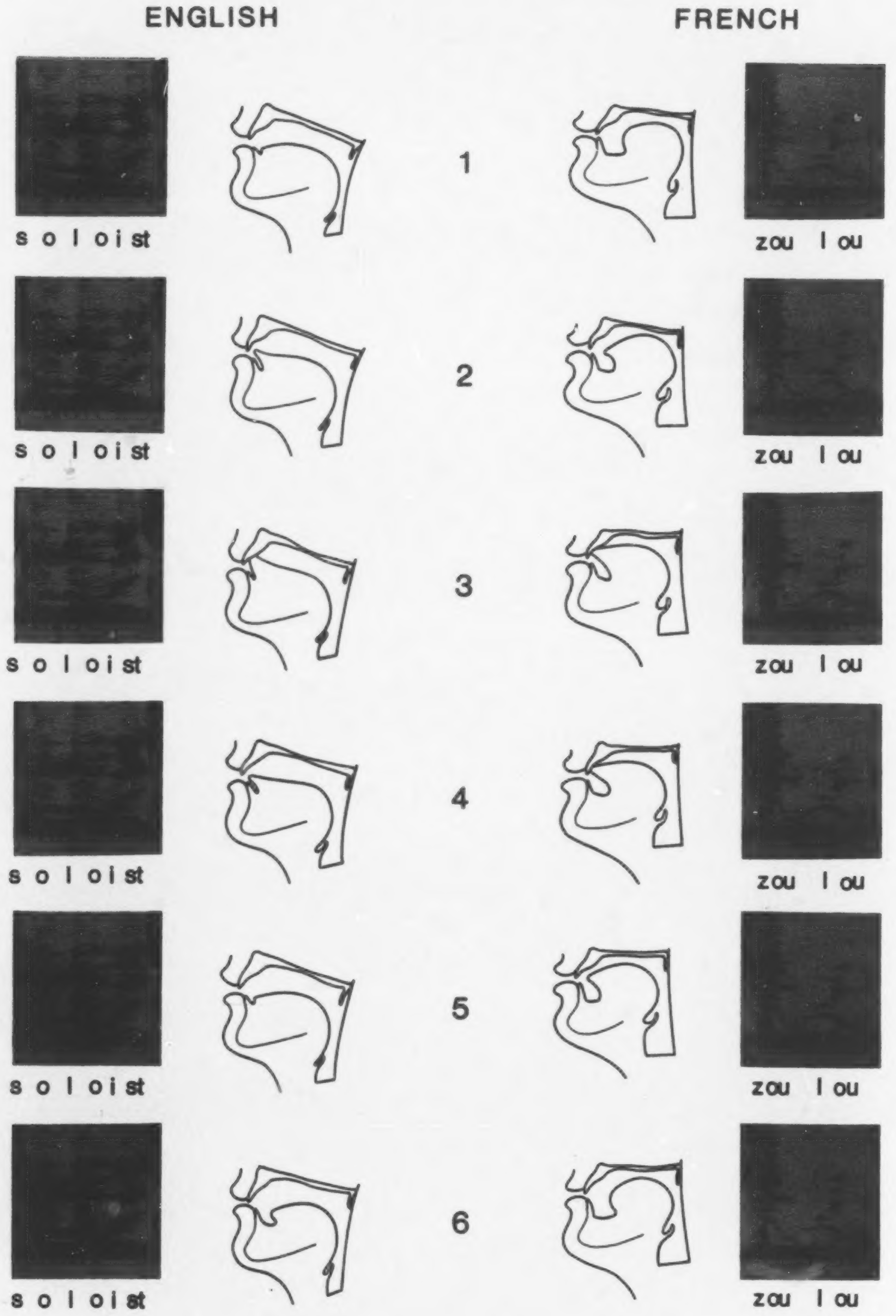
INTERVOCALIC /l/


ENGLISH
FRENCH
1
ba ll a de
ba ll a de
2
ba ll a de
ba ll a de
3
ba ll a de
ba ll a de
4
ba ll a de
ba ll a de
5
ba ll a de
ba ll a de
6
ba ll a de
ba ll a de

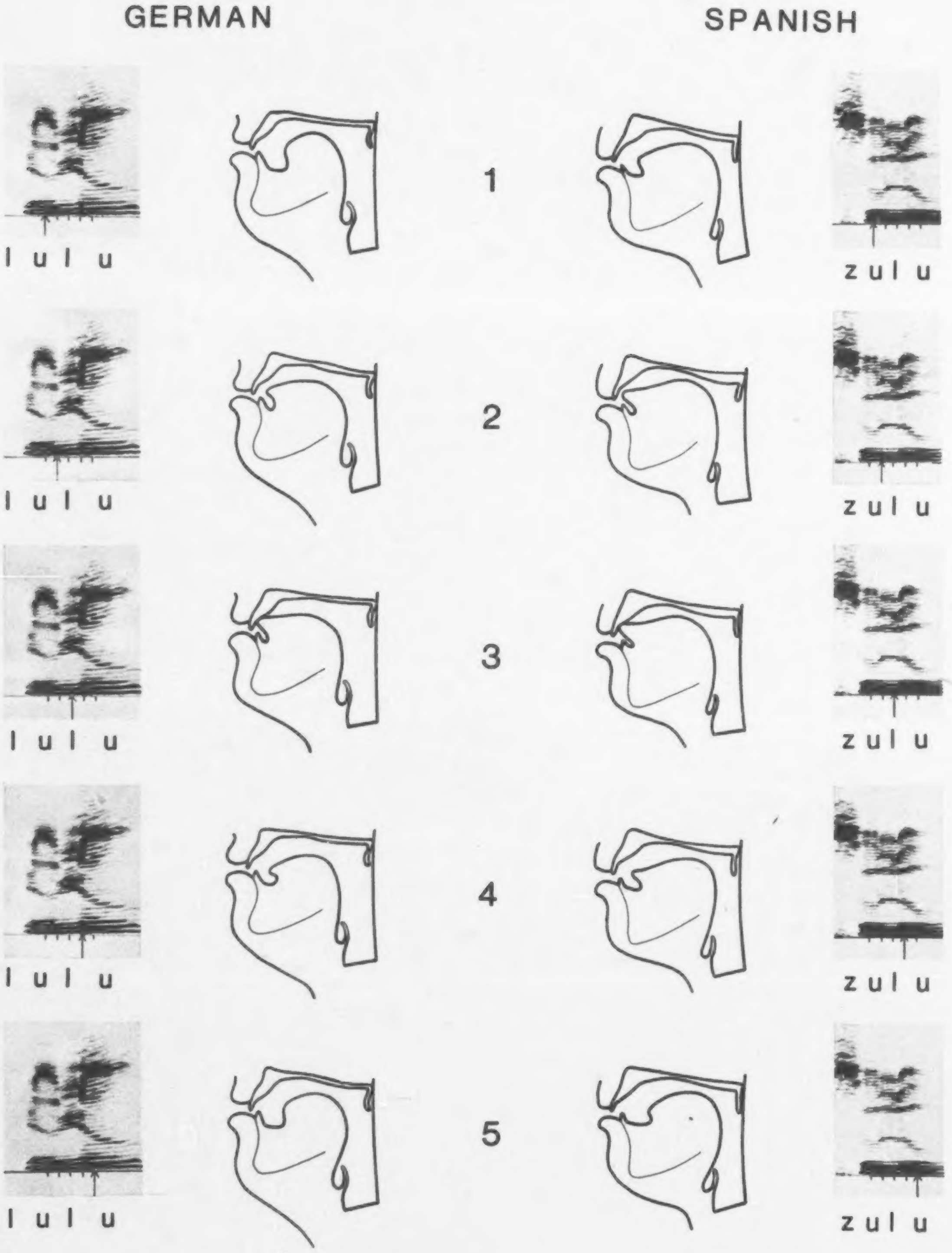
INTERVOCALIC /l/


GERMAN
SPANISH
1
ball a de
ba l a da
2
ball a de
ba l a da
3
ball a de
ba l a da
4
ball a de
ba l a da
5
ball a de
ba l a da

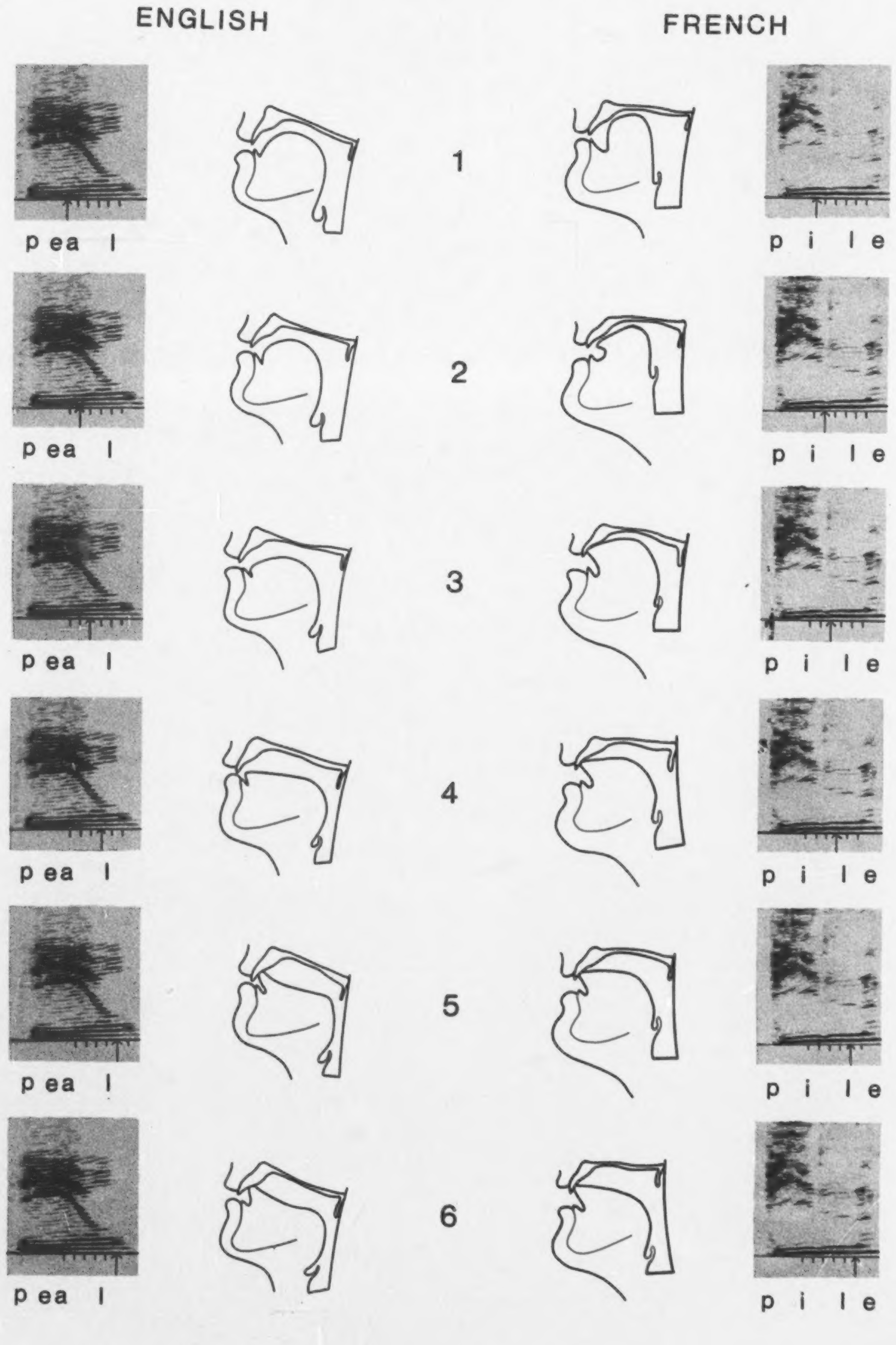
INTERVOCALIC /l/


ENGLISH
FRENCH
soloist
1
zou lou
soloist
2
zou lou
soloist
3
zou lou
soloist
4
zou lou
soloist
5
zou lou
soloist
6
zou lou

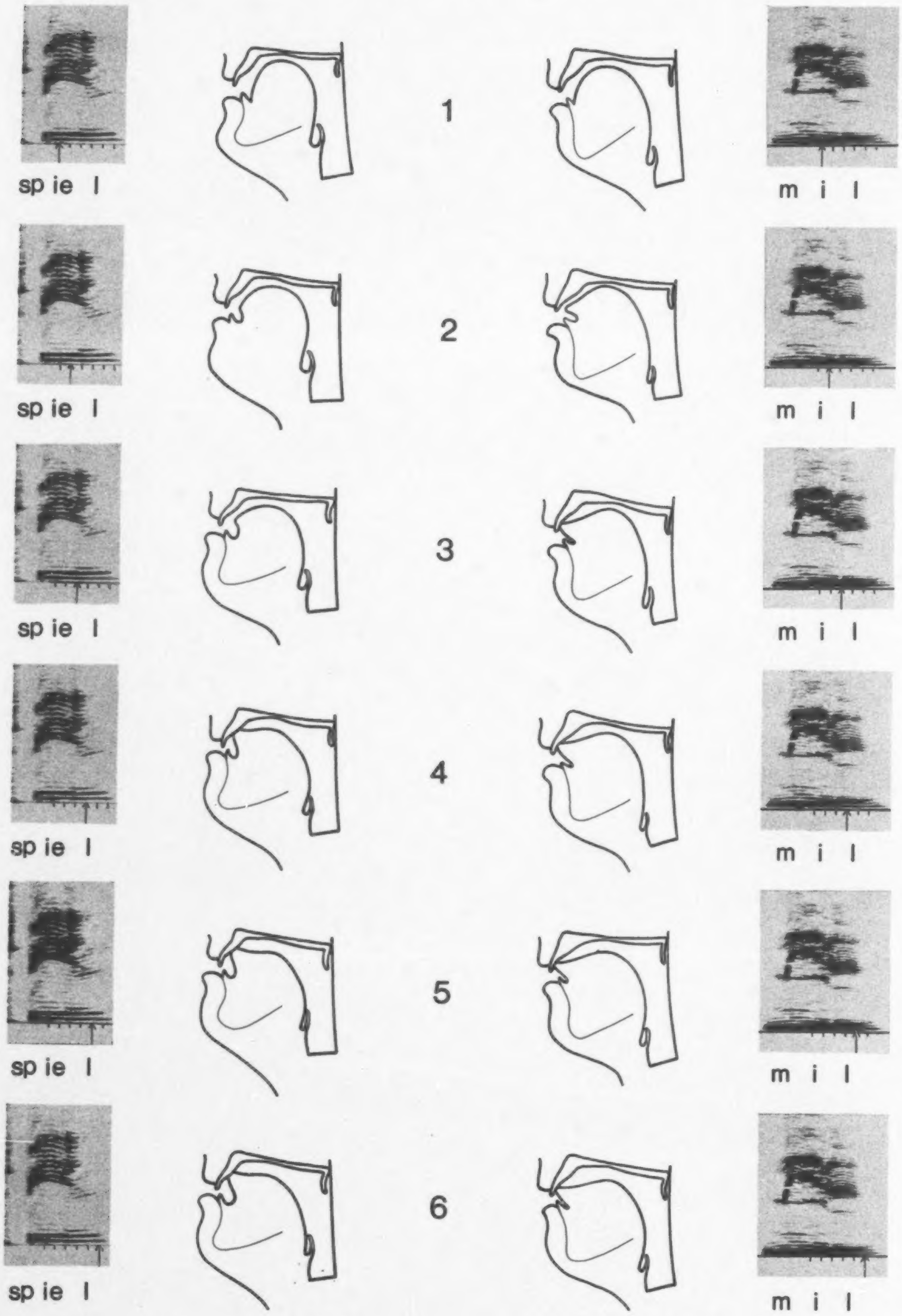
INTERVOCALIC /l/


GERMAN
SPANISH
1
2
3
4
5
l u l u
l u l u
l u l u
l u l u
l u l u
z u l u
z u l u
z u l u
z u l u
z u l u

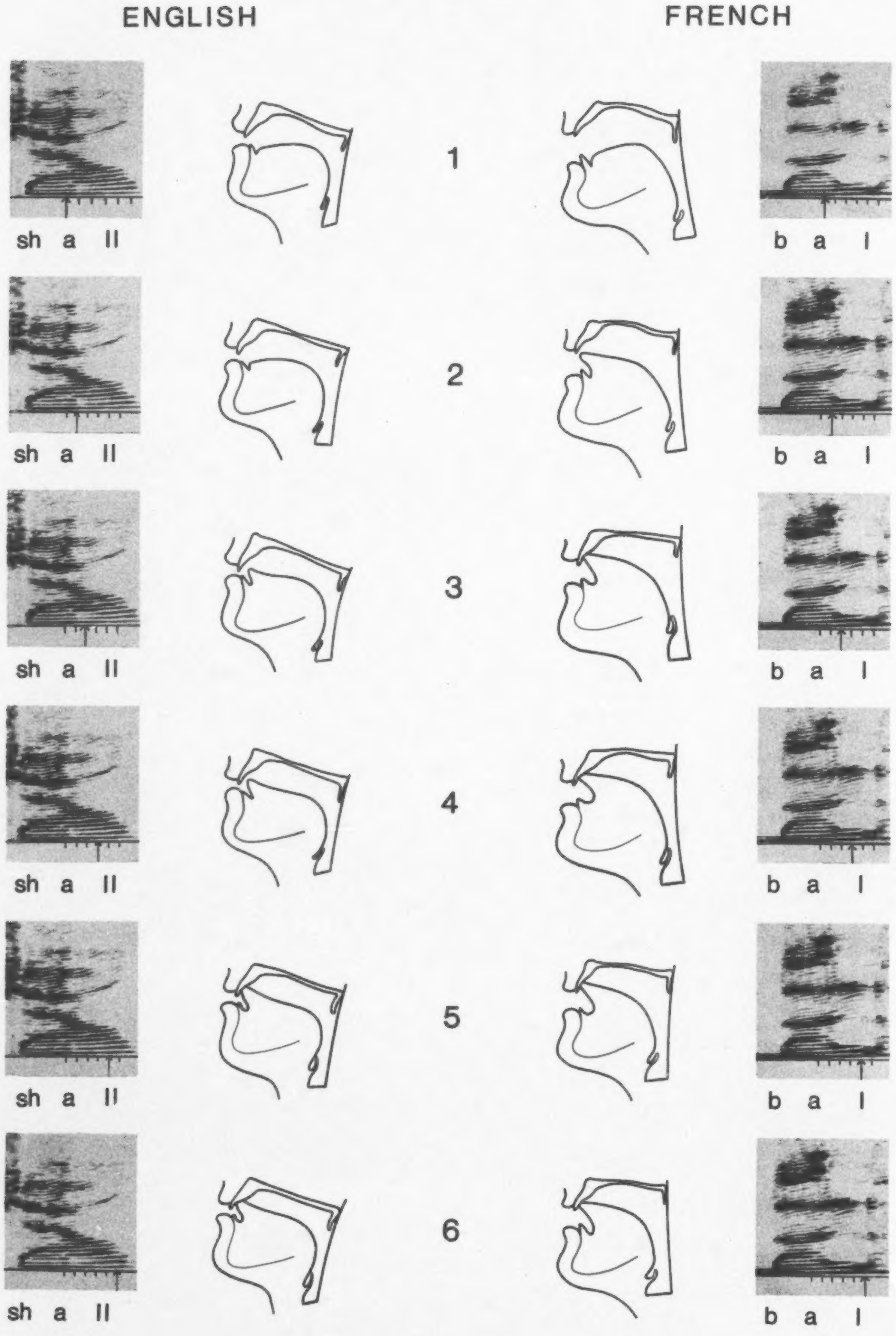
FINAL /l/


ENGLISH
FRENCH
1
2
3
4
5
6
p ea l
p ea l
p ea l
p ea l
p ea l
p ea l
p i l e
p i l e
p i l e
p i l e
p i l e
p i l e

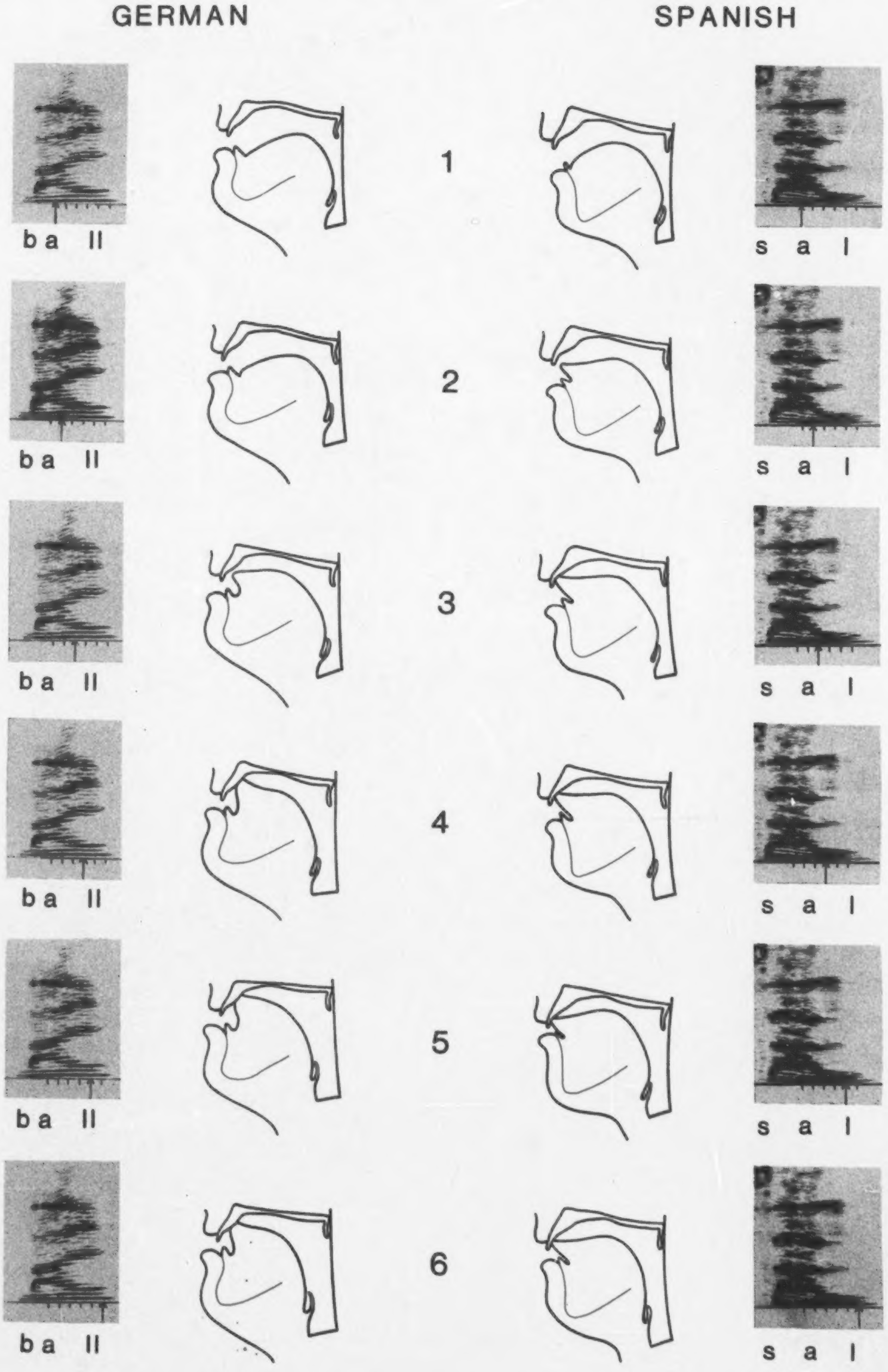
FINAL /l/


GERMAN
SPANISH
sp ie l
1
m i l
sp ie l
2
m i l
sp ie l
3
m i l
sp ie l
4
m i l
sp ie l
5
m i l
sp ie l
6
m i l

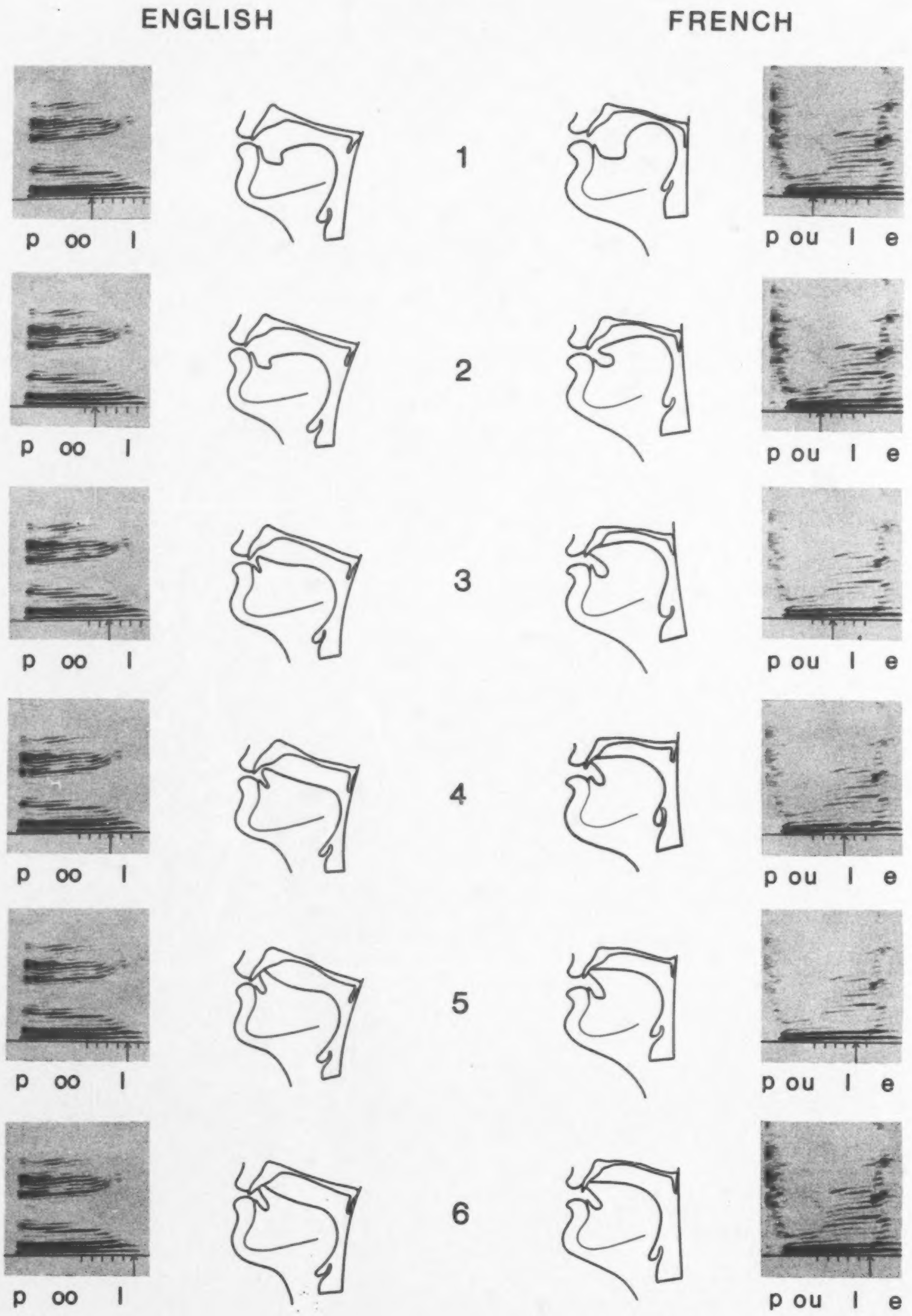
FINAL /l/


ENGLISH
FRENCH
1
sh a ll
b a l
2
sh a ll
b a l
3
sh a ll
b a l
4
sh a ll
b a l
5
sh a ll
b a l
6
sh a ll
b a l

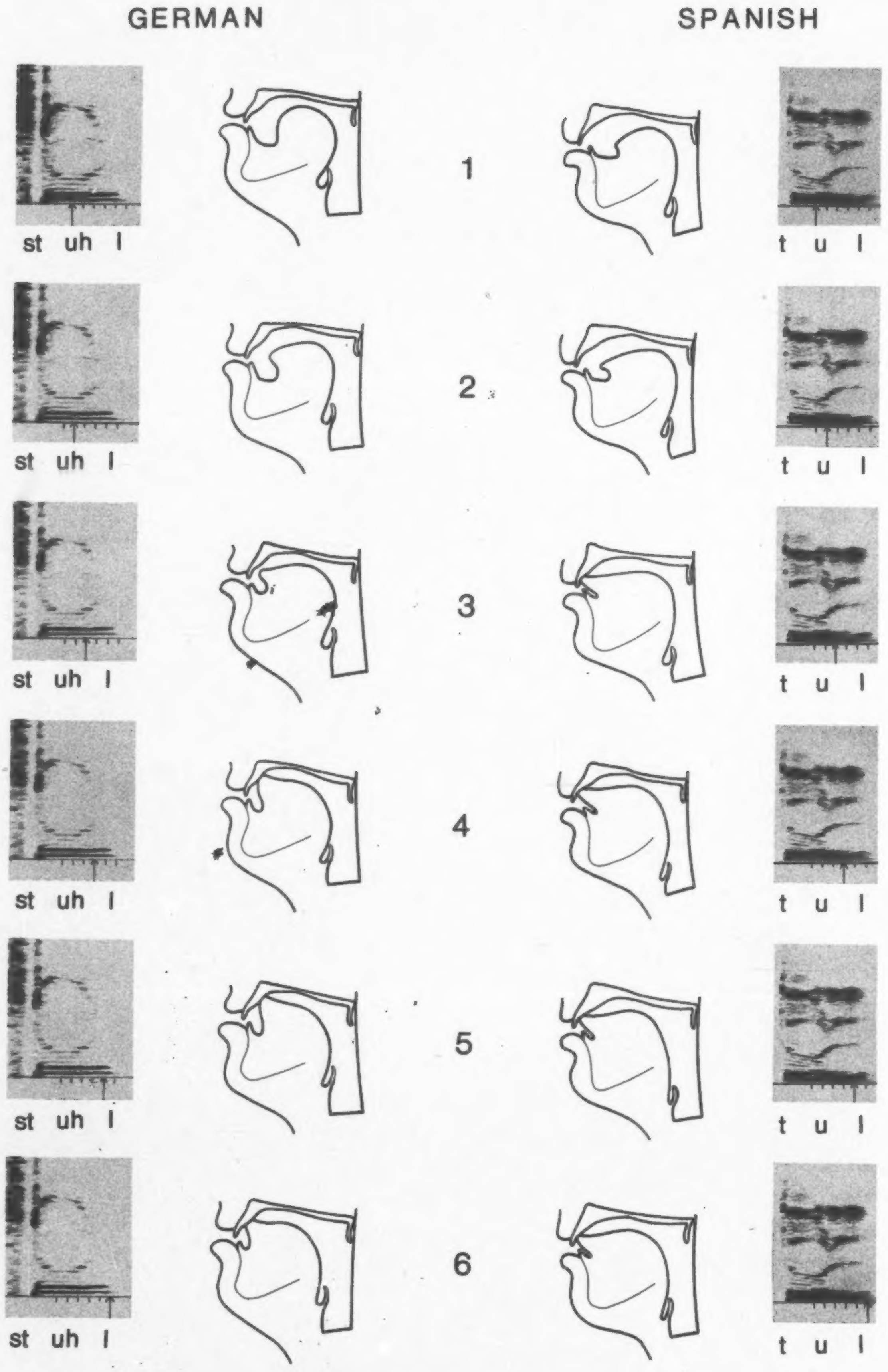
FINAL /l/


GERMAN
SPANISH
1
2
3
4
5
6
ba ll
ba ll
ba ll
ba ll
ba ll
ba ll
s a l
s a l
s a l
s a l
s a l
s a l

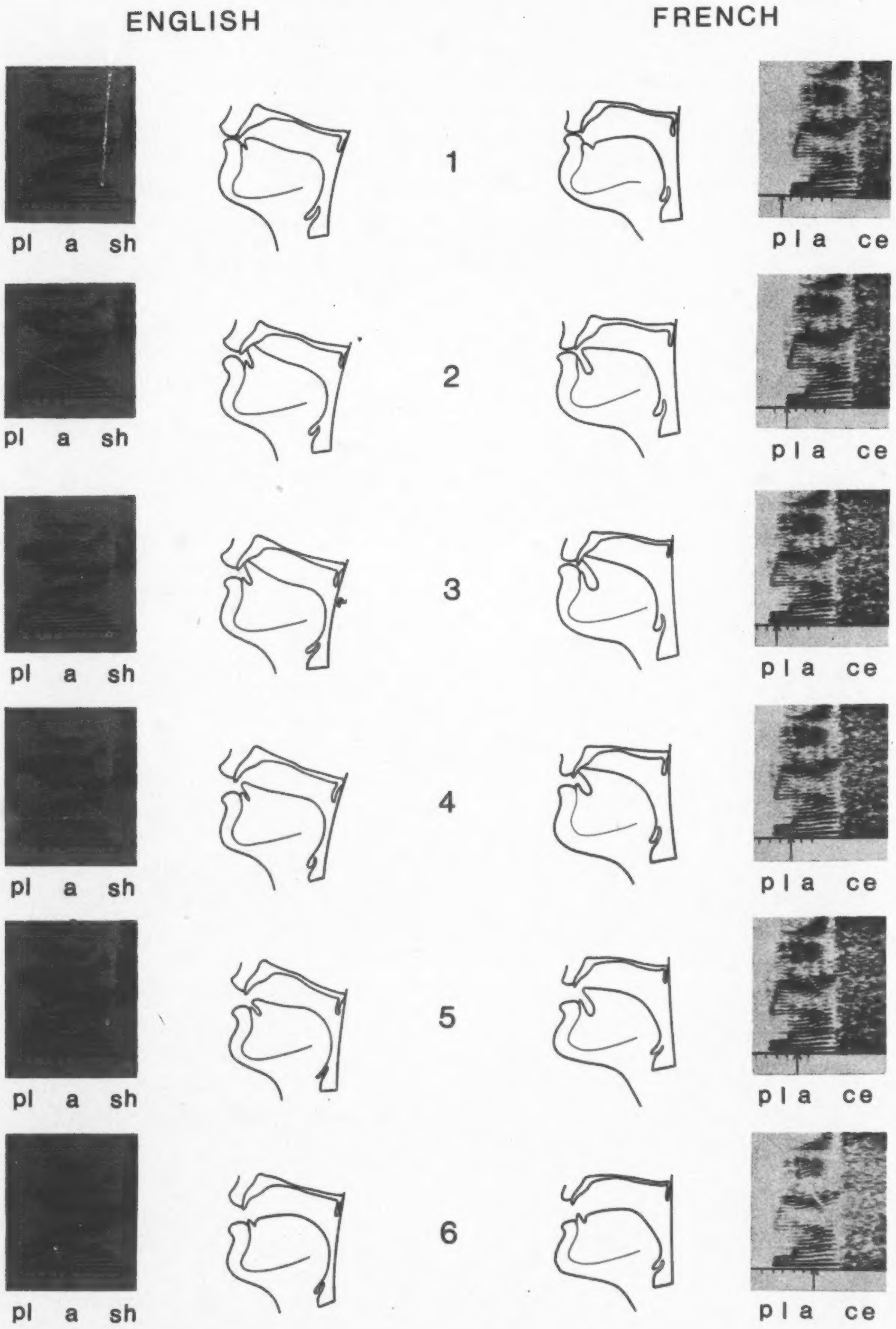
FINAL /l/


ENGLISH
FRENCH
1
2
3
4
5
6
p oo l
p oo l
p oo l
p oo l
p oo l
p oo l
p ou l e
p ou l e
p ou l e
p ou l e
p ou l e
p ou l e

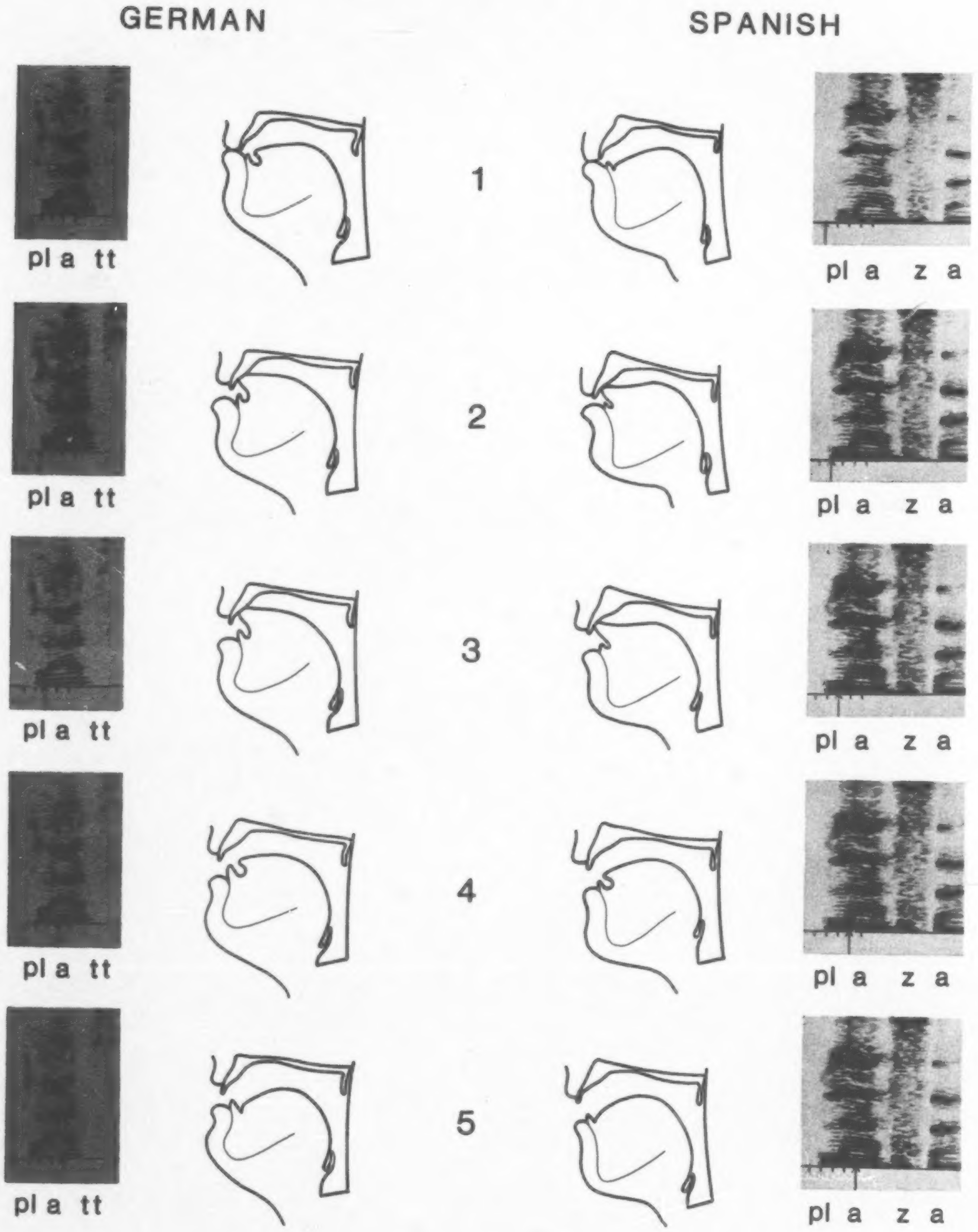
FINAL /l/


GERMAN
SPANISH
st uh l
1
t u l
st uh l
2
t u l
st uh l
3
t u l
st uh l
4
t u l
st uh l
5
t u l
st uh l
6
t u l

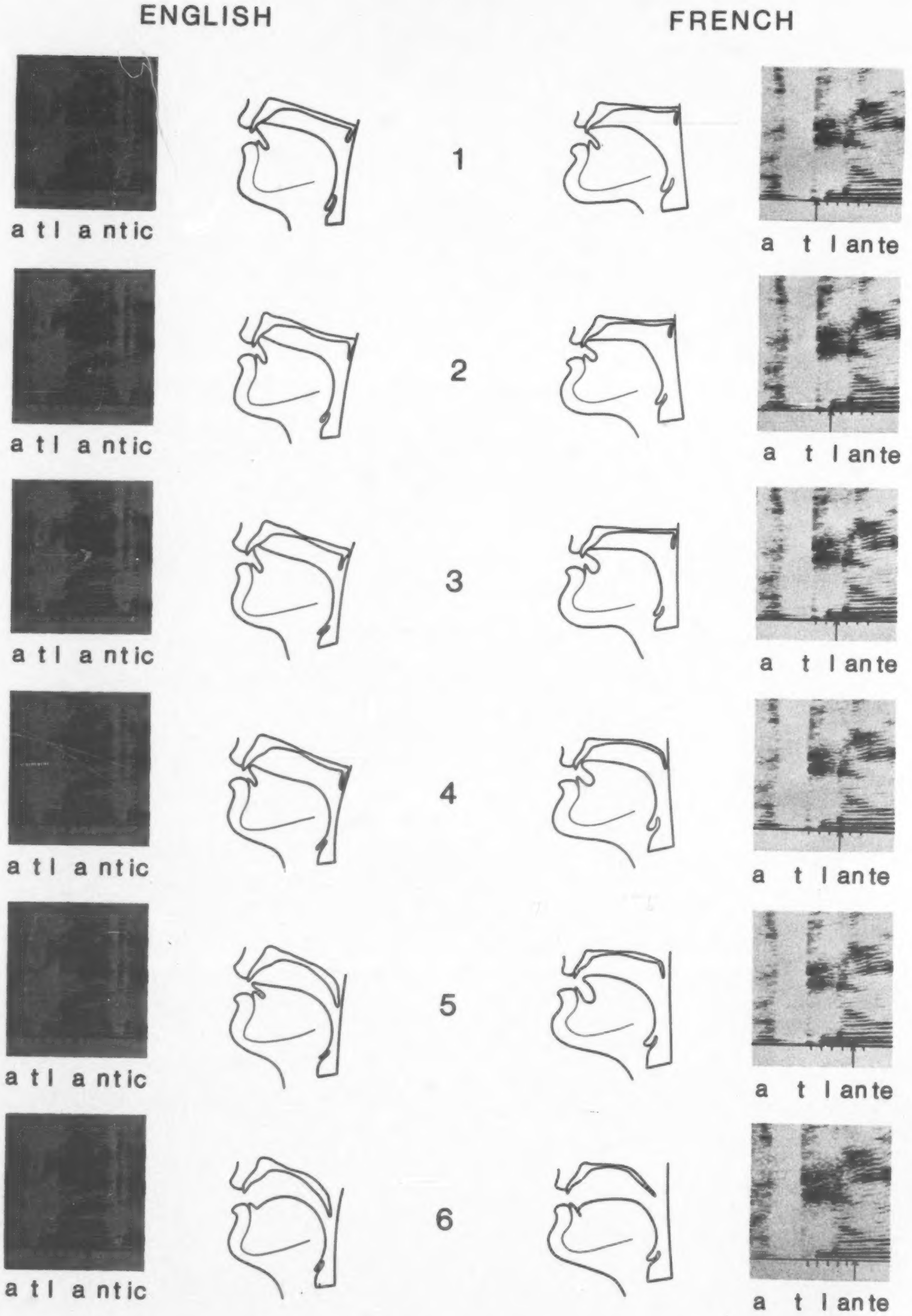
POST-CONSONANTAL /l/


ENGLISH
FRENCH
1
pl a sh
pla ce
2
pl a sh
pla ce
3
pl a sh
pla ce
4
pl a sh
pla ce
5
pl a sh
pla ce
6
pl a sh
pla ce

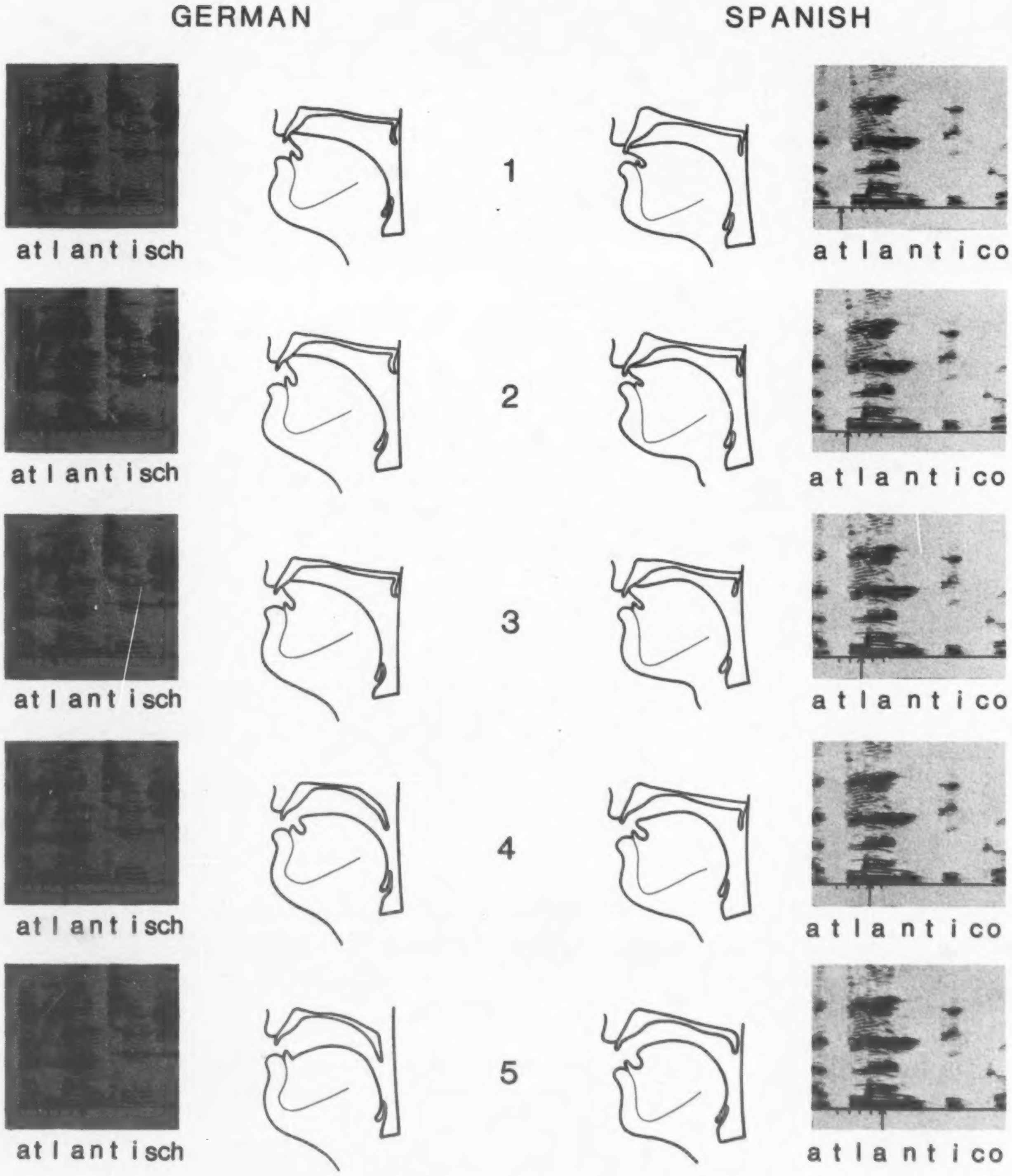
POST-CONSONANTAL /l/


GERMAN
SPANISH
pl a tt
1
pl a z a
pl a tt
2
pl a z a
pl a tt
3
pl a z a
pl a tt
4
pl a z a
pl a tt
5
pl a z a

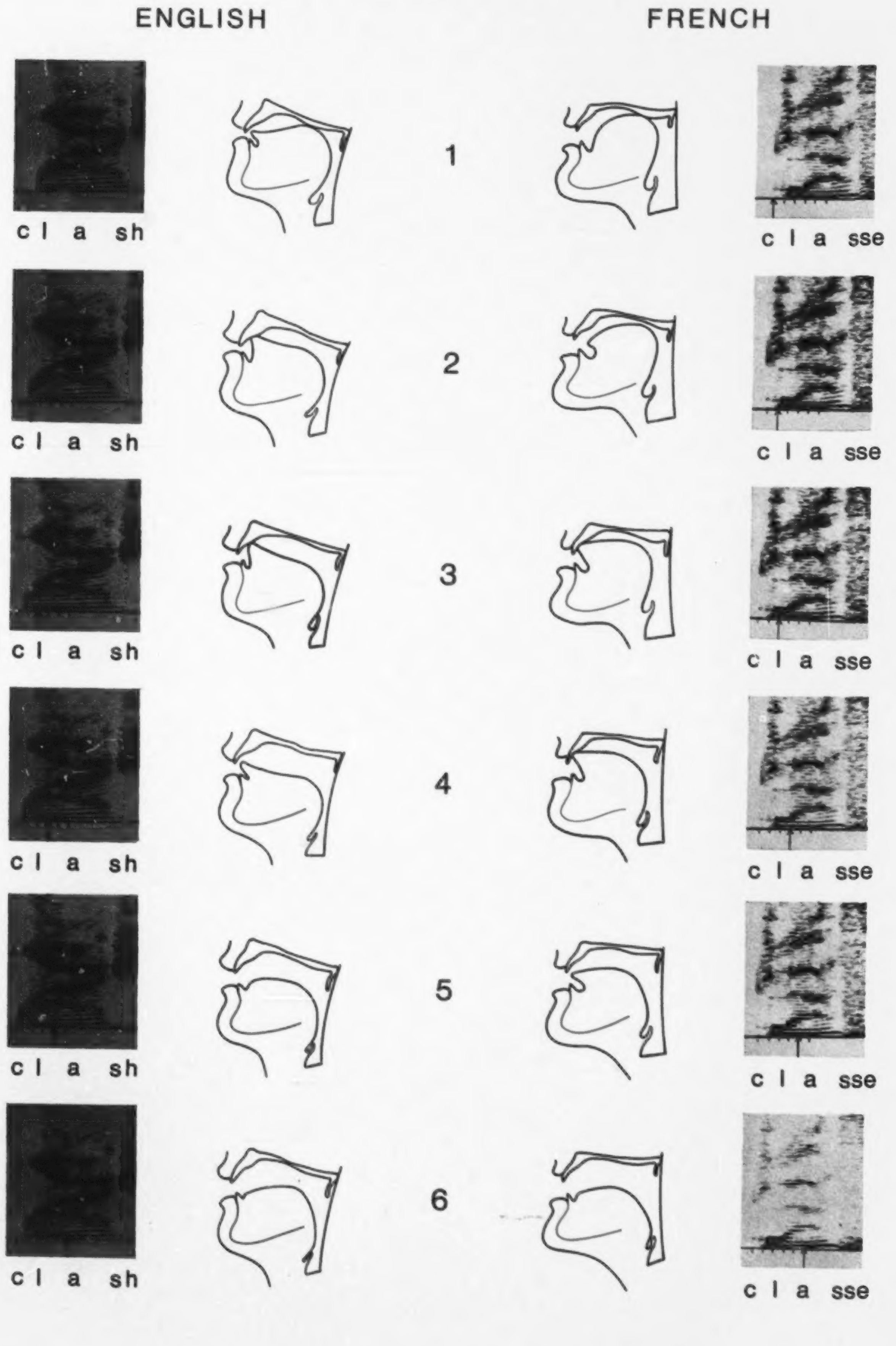
POST-CONSONANTAL /l/


ENGLISH
FRENCH
1
a tl a ntic
a t l ante
2
a tl a ntic
a t l ante
3
a tl a ntic
a t l ante
4
a tl a ntic
a t l ante
5
a tl a ntic
a t l ante
6
a tl a ntic
a t l ante

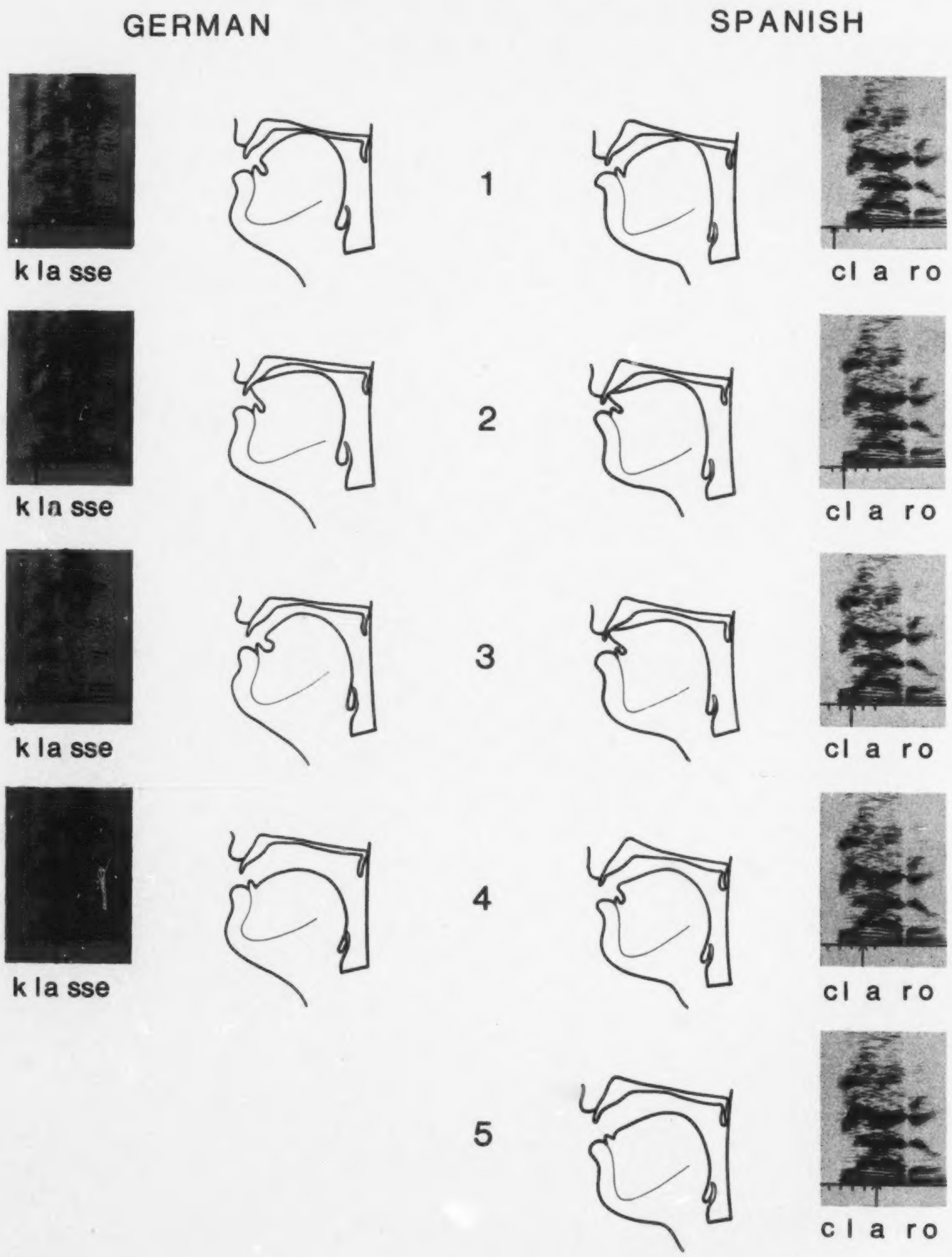
POST-CONSONANTAL /l/


GERMAN
SPANISH
1
at l ant isch
a t l a nt i co
2
at l ant isch
a t l a nt i co
3
at l ant isch
a t l a nt i co
4
at l ant isch
a t l a nt i co
5
at l ant isch
a t l a nt i co

POST-CONSONANTAL /l/


ENGLISH
FRENCH
1
2
3
4
5
6
c l a sh
c l a sse

POST-CONSONANTAL /l/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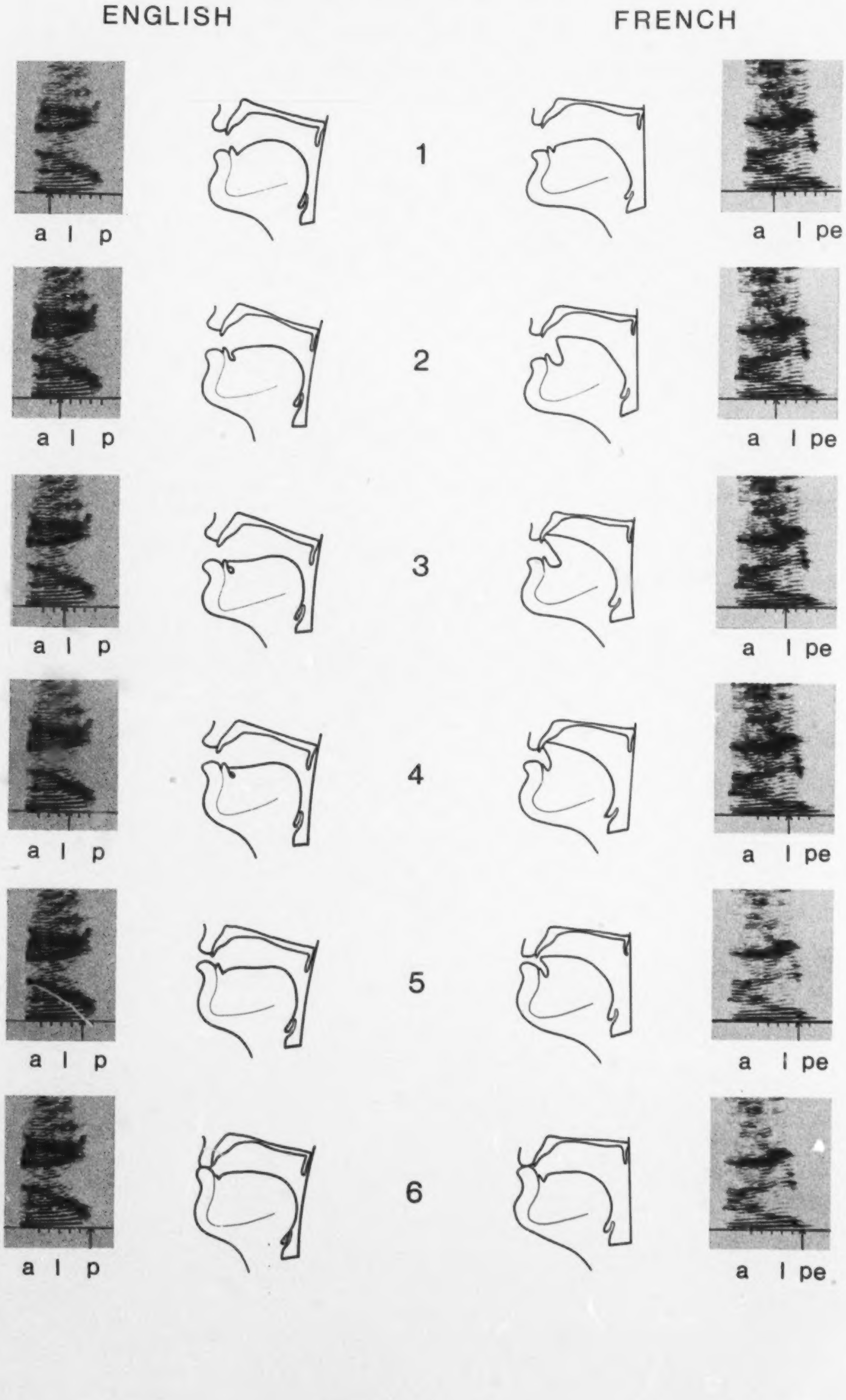
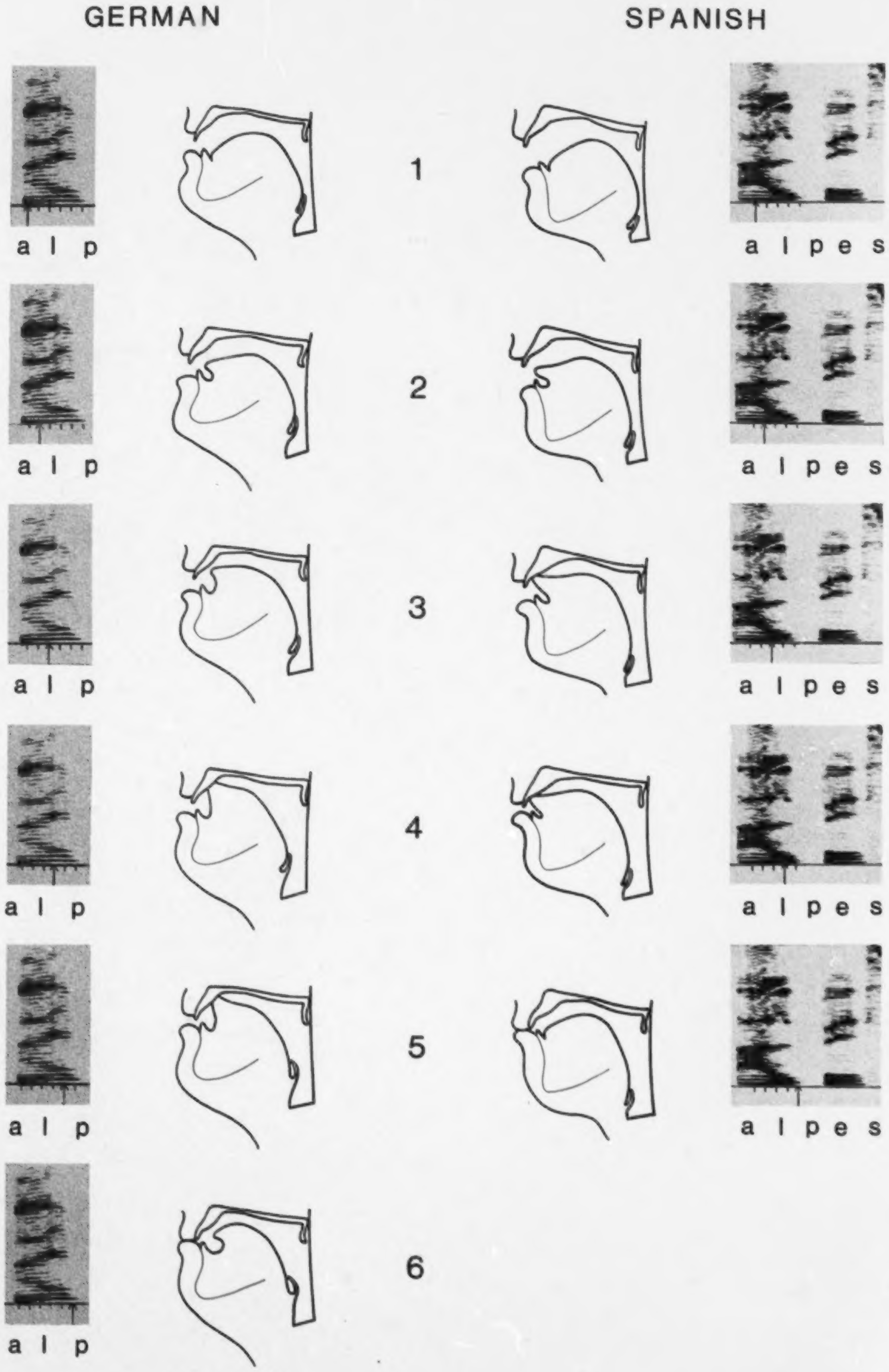
SPANISH
k la sse
1
cl a ro
k la sse
2
cl a ro
k la sse
3
cl a ro
k la sse
4
cl a ro
5
cl a ro

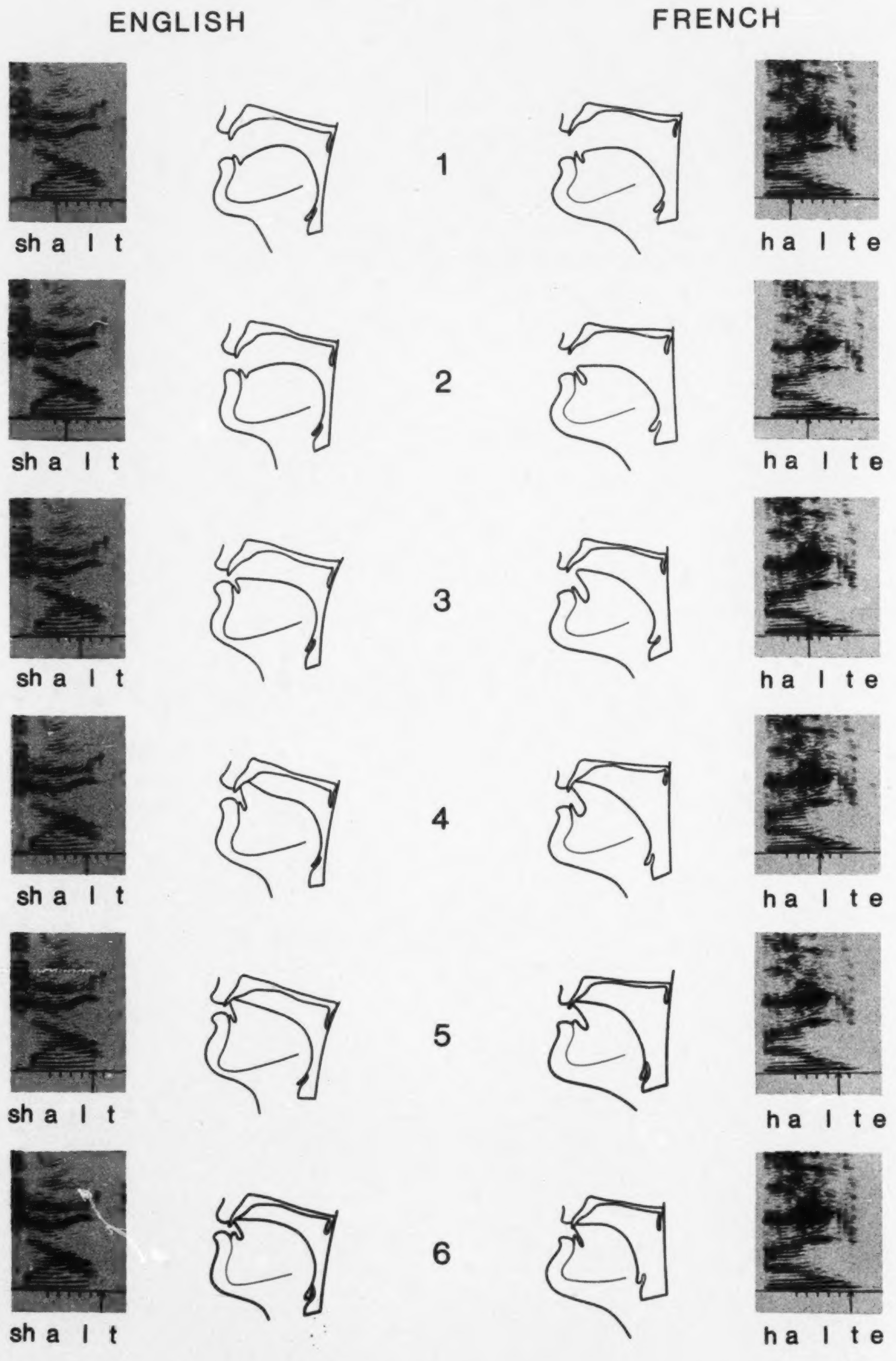
PRECONSONANTAL /l/


ENGLISH
FRENCH
1
2
3
4
5
6
a l p
a l pe

PRECONSONANTAL /l/


GERMAN
SPANISH
1
a l p
a l p e s
2
a l p
a l p e s
3
a l p
a l p e s
4
a l p
a l p e s
5
a l p
a l p e s
6
a l p

PRECONSONANTAL /l/


ENGLISH
FRENCH
1
sh a l t
ha l te
2
sh a l t
ha l te
3
sh a l t
ha l te
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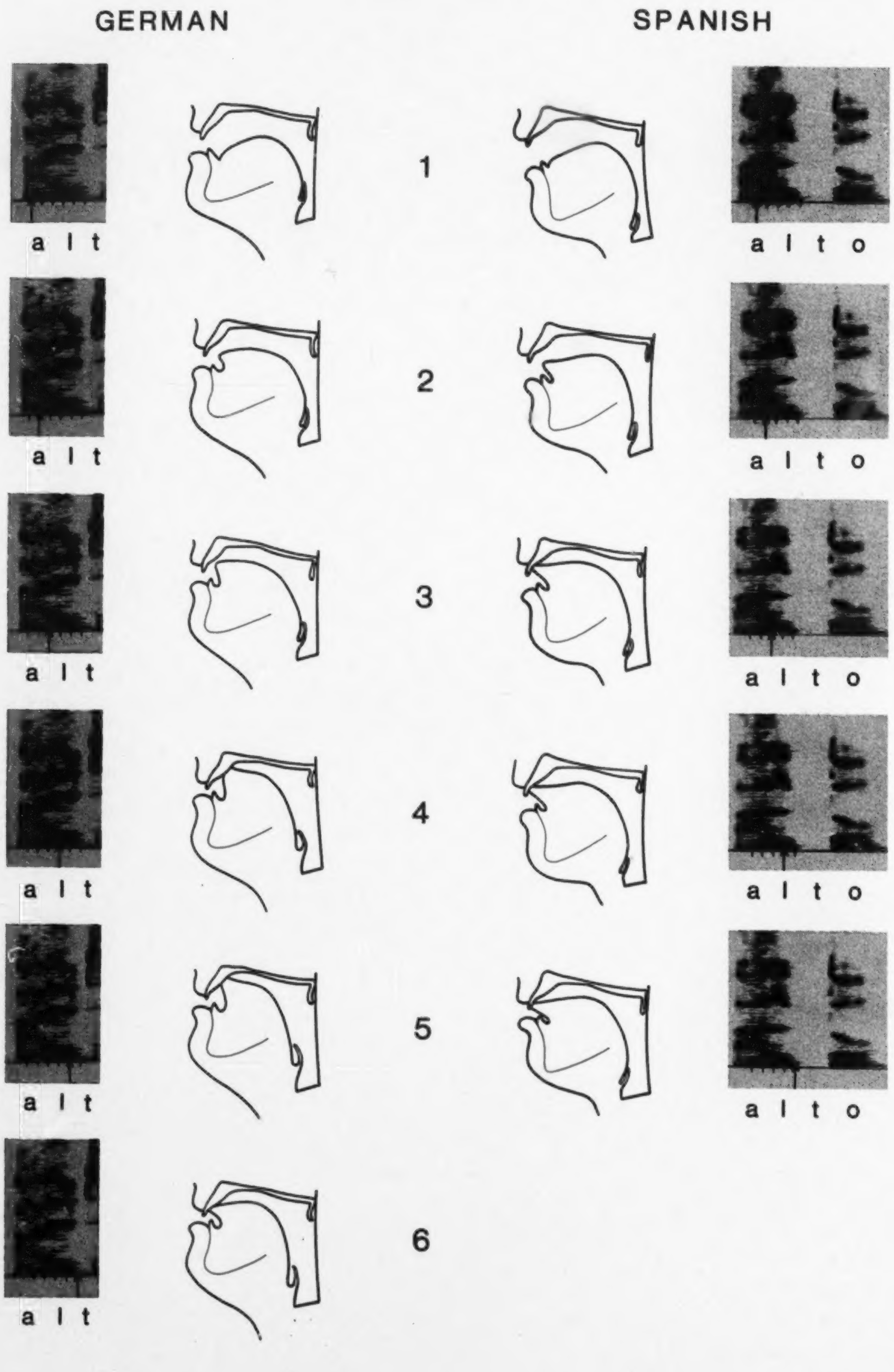
sh a l t
ha l te
5
sh a l t
ha l te
6
sh a l t
ha l te

PRECONSONANTAL /l/


GERMAN
SPANISH
1
a l t
a l t o
2
a l t
a l t o
3
a l t
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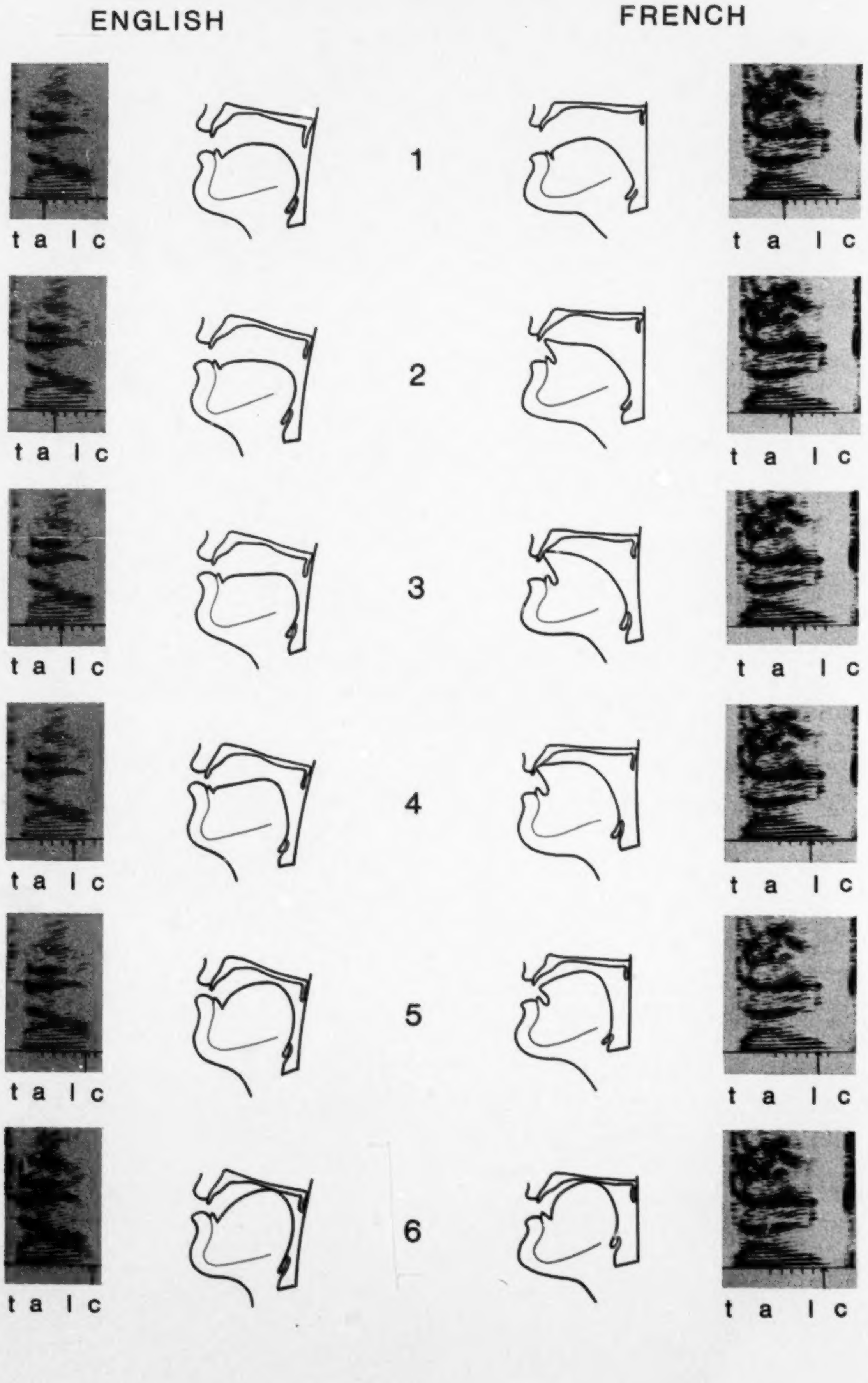
4
a l t
a l t o
5
a l t
a l t o
6
a l t

PRECONSONANTAL /l/


ENGLISH
FRENCH
t a l c
1
t a l c
t a l c
2
t a l c
t a l c
3
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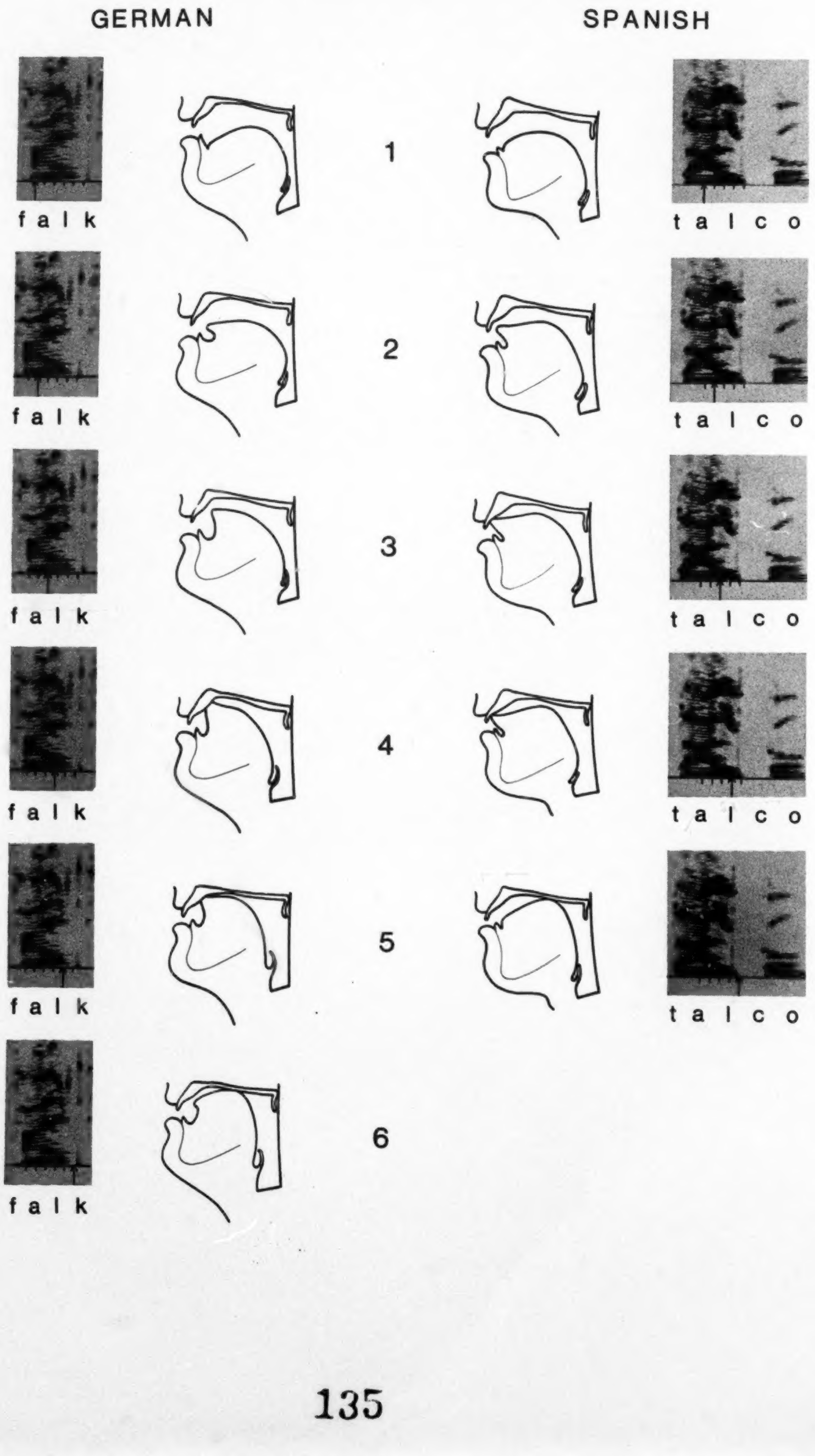
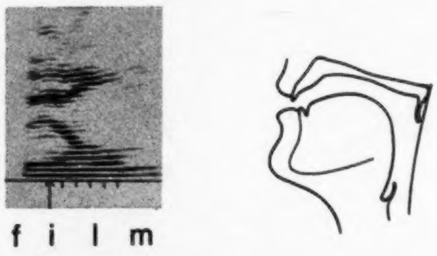
t a l c
4
t a l c
t a l c
5
t a l c
t a l c
6
t a l c

PRECONSONANTAL /l/


GERMAN
SPANISH
1
falk
talco
2
falk
talco
3
falk
talco
4
falk
talco
5
falk
talco
6
falk

PRECONSONANTAL /l/

ENGLISH **FRENCH**



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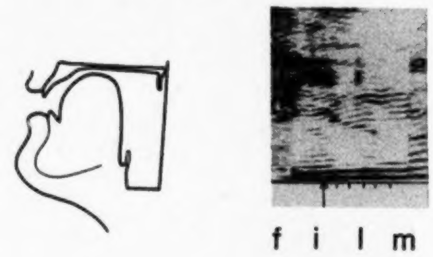

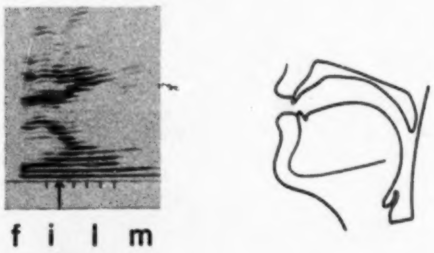

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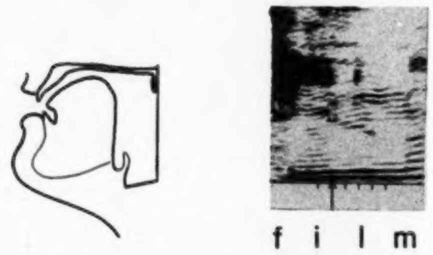

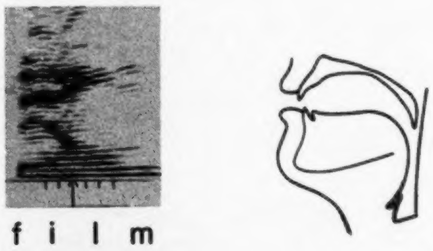

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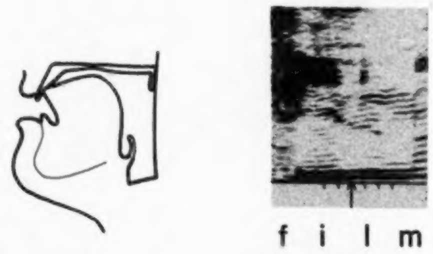

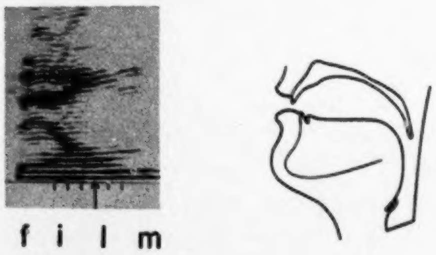

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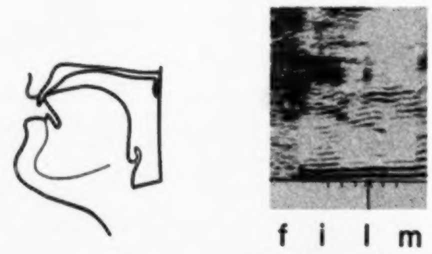

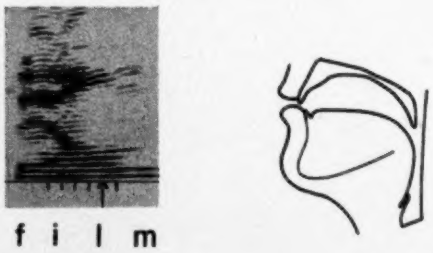

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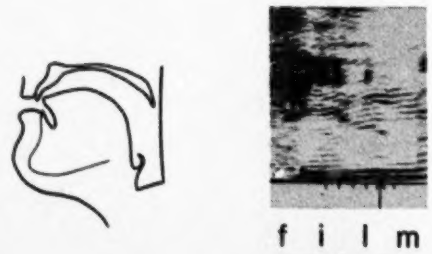

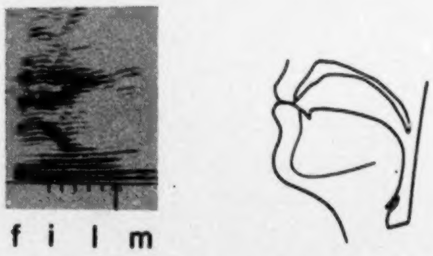

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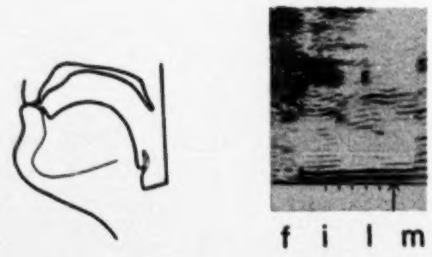
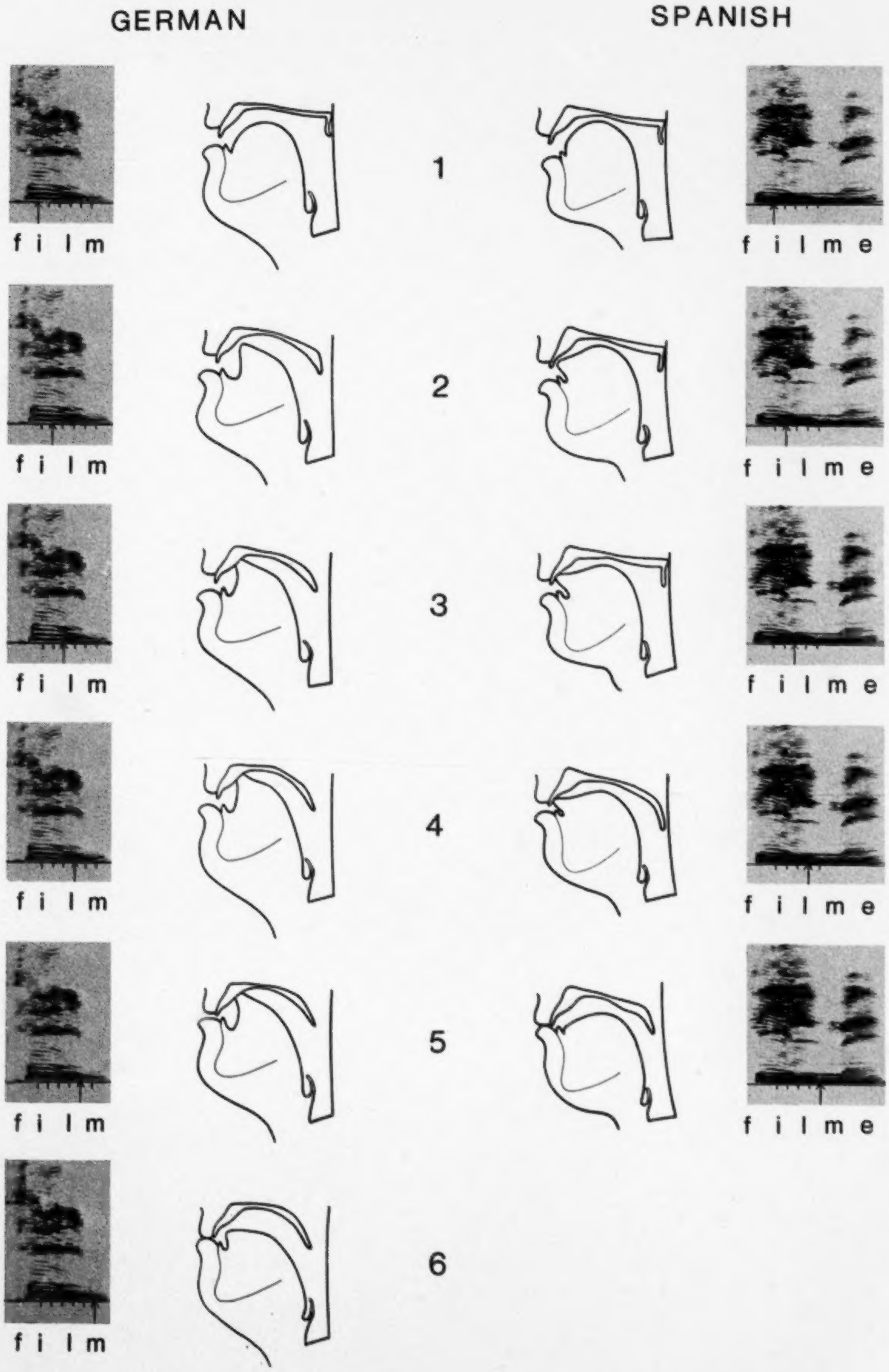


PRECONSONANTAL /l/


GERMAN
SPANISH
1
f i l m
f i l m e
2
f i l m
f i l m e
3
f i l m
f i l m e
4
f i l m
f i l m e
5
f i l m
f i l m e
6
f i l m

THE TEACHING OF 'CLEAR' VERSUS 'DARK' /l/
IN ENGLISH, FRENCH, GERMAN AND SPANISH

INTRODUCTION

Present techniques of teaching foreign languages do not reflect adequate exploitation of the results of basic linguistic research such as those presented in this report. The teaching of pronunciation in particular suffers on the one hand from misconceptions as to what actually are the articulatory habits of native educated speakers of the target languages, and on the other from ignorance as to what sensory modalities are involved in the perception, conception and proprioception of the phonetic elements of speech. This section of our report is offered as a model for the solution of these difficulties. Our intent has been twofold: 1) to present a theoretical basis from which specialists in foreign language teaching can develop materials, and 2) to demonstrate the application of our findings to teaching the pronunciation of a phoneme that is one of the most difficult for Anglo-Americans to acquire and one of the most crucial in characterizing Western European languages, as opposed to English.

One of the most important discoveries in Experimental Phonetics in recent years is that the perception of speech signals is fundamentally different and much more complex than the perception of other auditory signals, such as music. Different neurological mechanisms are involved, and the decoding of the incoming signal, as well as the manner in which the phonemic entities are stored cerebrally, involves sensory modalities other than hearing and acoustic mapping. Inasmuch as the detail of the basic research is now common knowledge in the speech sciences, we shall limit ourselves here to a brief summary of the main pertinent principles.

It now appears that only vowels can be adequately decoded by reference to stored acoustic impressions alone, and the perception of even this class of phonemes is doubtless enhanced by some degree of reference back to articulation. What we mean by this is that the listener, in the process of identifying a vowel, will process it exactly as he does a musical chord, that is, he will judge the spacing and relative values of the vowel's formants, and recognize it psychologically in the same way as he does a 'major', 'minor', or 'diminished' chord. Relativity here is important, for, just as a major chord can occur in every conceivable musical key and still retain the same color, so will a given vowel, /a/ for example, vary in its absolute values from one voice to another. At the same time, articulatory proprioception no doubt plays a secondary and supporting role in vowel perception. Each vowel is more or less characterized by an articulation, which in production gives rise to stereognostic and kinesthetic feedback, primarily to the parietal cortex (areas 5 and 7). Finally and to a much lesser degree, visual cues, for those aspects of articulation that can be seen (lip and mandible positions, some apical movements or positions, etc.), no doubt reinforce articulatory proprioception, when such cues are present.

In the perception of consonants, the relative importance of acoustic versus articulatory reference appears to be the opposite from what occurs in vowel perception. Whereas there exists a close relationship between the acoustic signal and the identity of vowels, making decoding possible by direct reference to stored acoustic entities, such a relationship is often absent in the case of consonants. This becomes immediately apparent when one examines the many different formant transitions or burst frequencies that characterize a given consonant as it is associated with different vowels. The only thing approximating a one-to-one physical to conceptual relationship in the case of consonants is their articulation: A /k/ is always velar, a /d/ is always alveolar, regardless of their changing burst frequencies or transitions. While it is true that the identity of a consonant is ultimately transmitted from speaker to listener via acoustic signals, they must necessarily be decoded by reference back to articulation. As Baudouin de Courtenay put it, "In order to understand, you must imagine that you yourself are doing the speaking." What Courtenay did not realize at the time was that this would be found to apply mainly to consonants and that we would call the process "subvocalization".

The consequences of these discoveries to education are obvious: To teach vowels, we must maximize listening and imitation in the Language Laboratory and not waste too much time describing their articulation. In this respect, it must be remembered that considerably different articulations can (and often do) produce the same acoustic signal for a given vowel. To teach consonants, however, the instructor must emphasize articulation and provide models such as the materials for /l/ being submitted with this report. Although some work in the Language Laboratory undoubtedly helps in learning to pronounce consonants, it plays a very secondary role in the acquisition of proper habits and cannot suffice by itself.

For the sake of clarity, we have purposely given a grossly simplified description of speech perception. The explanation given above is most true for the most open and fully voiced vowels and for the consonants that have the smallest apertures (the stops) and the least voicing. As we go from one extreme (the vowel /a/) to the other (/k/), the relative importance of acoustic reference and articulatory reference slowly shifts from the first to the second. In the center of the gamut of phonemes are the liquids, semi-consonants and nasal consonants, and these probably represent an almost even balance (in terms of importance) of both acoustic and articulatory feedback cues. Obviously the teaching of these entities is best accomplished if both acoustic and articulatory models are provided.

'Clear' /l/ is crucial to the acquisition of a good accent in French, German and Spanish because of its very distinctive sound and because of the great influence it has on contiguous phonemes. Actually, it embodies most of the aspects of the 'oral posture' that forms the basis of the accent of the languages in question, and it serves as frame of reference and point of departure for all articulations. Thus an accurate definition of the /l/ is in essence a rather comprehensive description of the articulatory habits of the language. Since from all points of view, /l/ embodies both vowel and consonant features (the resonant, voiced steady-state of the former and the articulatory contact and fast transition rates of the latter), it is taught best with both auditory and articulatory models. The student will require a thorough articulatory description of its nature, reinforced with appropriate visual aids, and authentic models of the /l/ sound recorded on tape for use in the Language Laboratory. Accordingly, our presentation will include: (a) an articulatory description of /l/, (b) visual aids in the form of transparencies traced from X-ray films, and flip-cards, and (c) examples of tape-recorded exercises for the Language Laboratory.

In translating the results of our research into practical teaching methods, a great deal of simplification is obviously necessary. The minutiae are of interest mainly to the linguist and to the graduate student. The beginning student in foreign language must have something simple to understand and easy to master. Actually, the small differences that occur in both varieties of /l/ as a function of position in the utterance and phonetic context can be reduced to a common 'dark' /l/ for English and one 'clear' /l/ for each of the three other languages that is perfectly acceptable in all positions.

EXPLANATIONS FOR AMERICAN STUDENTS

The following points should be explained to American students, either in their textbooks or verbally by the teacher: English has an /l/ that we call 'dark' because its steady-state portion sounds much like the vowel of book, took, crook, etc. It is so much like that vowel that the latter is often substituted for it when /l/ occurs before another consonant; would, could, and the like, have long lost their /l/, and many other words, like help, are in the process of doing so. Many people now say "help", "Ralph", "scalp", etc., without ever making contact between their tongue tip and the roof of their mouth, and a listener would have considerable difficulty telling the difference. This dark quality of /l/ and the instability of that consonant are very strong characteristics of the American and English accents and must be avoided in the target language. The behavior of the tongue during the articulation of English 'dark' /l/ must be understood by the student before he can acquire the 'clear' /l/. In the series of overlays and flip cards for English /il/ submitted with this report, the rounded contour of the tongue for the vowel is seen to give way to a concave profile as the central portion drops toward the floor of the mouth and the tip curls upward to make contact with the alveolar ridge (the furrowed area behind the upper gums). The student must start by repeating this movement a number of times, focusing his attention on the proprioceptive articulatory sensations arising from this gesture, in order to become fully conscious of what he is to avoid in the target language.

'Clear' /l/ differs in two important respects: First, the point of tongue-tip contact is much farther forward than in English, the tip touching the line separating the upper teeth from the gums. Second, the central portion of the tongue does not assume a concave profile, except to a very slight degree, in our Spanish sample. The position of the tip of the tongue for 'clear' /l/ makes it profitable for the student to practice with a mirror, as, unlike 'dark' /l/, it is visible from outside in French, German and Spanish.

The flip cards for French pile /pil/begin well into the vowel /i/--notice that even though the back of the tongue lowers during the /l/ portion, it remains convex throughout the entire articulation. The German articulation is virtually the same as French. The Spanish articulation differs in the very slight concavity described above.

SAMPLE TEACHING MATERIALS

Three types of materials are submitted as models for future development: 1) overlays for overhead projector in each of the four languages studied, 2) flip cards in each language showing the same sequence as in the overlays, and 3) tape-recorded exercises for French, German and Spanish, the texts of which follow . Additional sequences of flip cards in the four languages could readily be made from the X-ray sequences given in the chapter on 'clear' versus 'dark' /l/ in the present report.

French 'clear' /l/

1) Key word: pile (battery, pile)--to be practiced with flip cards and tape recording.

2) Single words with /l/ from the 1500 most frequently used words in French conversation.

a) Final position.

After /a/: mal, hôpital.
/ɛ/: hôtel, sel
/œ/: seul, veulent
/ɔ/: école, molle
/u/: poule, roule

b) Initial position.

Before /a/: là, laver
/ã/: lancer, langue
/ɛ/: laisser, lettre
/e/: laisse, légume
/i/: lit, livre
/y/: lu, lunettes

c) Pre-consonantal.

cultiver, film, résultat

d) Post-consonantal.

blesser, clef, glace, plat

e) Coherent sentences

Louis lit dans le silence de la salle.
Quel plaisir d'aller loin de la ville!
Elle est obligée de lui laisser l'enveloppe.
Il y a plusieurs malades à l'hôpital.
Il a plu tout le long de la vallée.

German 'clear' /l/

1) Key word: Spiel (game)--to be practiced with flip cards and tape recording.

2) Single words with /l/ from the 700 most frequently used words in German conversation.

a) Final position.

After /a/: Fussball, Fall
/ɛ/: schnell, hell
/ɔ/: voll, soll
/aI/: Teil, weil
/i/: viel, Spiel

b) Initial position.

Before /a/: Land, lassen
/e/: lesen, Lehrer
/i/: lieben, Lied
/U/: Luft, lustig
/aI/: leider, leisten

c) Pre-consonantal.

Welt, halb, Film, Volk, elf, Milch, Holz, falsch

d) Post-consonantal.

klein, gleich, Plan, schlecht, Blume, pflegen, nämlich, sammeln

e) Coherent sentences.

Leute pflegen kleine blaue Blumen viel.

Leider ist das Zigeunerleben nicht überall lustig.

Dem Volk gefällt das liebe Spiel.

Der Lehrer sammelt alte Volkslieder.

Damals lebte der Soldat im kalten Walde.

Spanish 'clear' /l/

1) Key word: *mil* (thousand)--to be practiced with flip cards and tape recording.

2) Single words with /l/ from basic conversational Spanish.

a) Final position.

After /a/: *al*, *ideal*
/e/: *el*, *aquel*
/i/: *mil*, *fácil*
/o/: *árbol*, *español*
/u/: *azul*

b) Initial position.

Before /a/: *la*, *lago*
/e/: *le*, *lengua*
/i/: *libre*, *libro*
/o/: *lo*, *los*
/u/: *luna*, *lugar*

c) Pre-consonantal.

algo, *alto*, *olvidar*, *almorzar*, *valdré*, *vals*

d) Post-consonantal.

claro, *doblar*, *plano*, *blanco*, *inglés*, *conflicto*

e) Coherent sentences.

Lunchando en la loma, liberaron a los ladrones.

La milicia, malaconsejada, utilizaba elefantes.

El barril de col se cubrió con papel.

Hay esclavos flacos en la plaza de San Blas.

Orlando implora que se aclare el asunto.

Salvador el alcalde sabrá la altura de la palmera delgada.

Algo está en la bolsa de Elsa.